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20TH ONTARIO INDUSTRIAL WASTE CONFERENCE

JUNE 1973
TORONTO, ONTARIO

PROCEEDINGS

Ontario

MINISTRY OF THE ENVIRONMENT

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MINISTRY OF THE ENVIRONMENT

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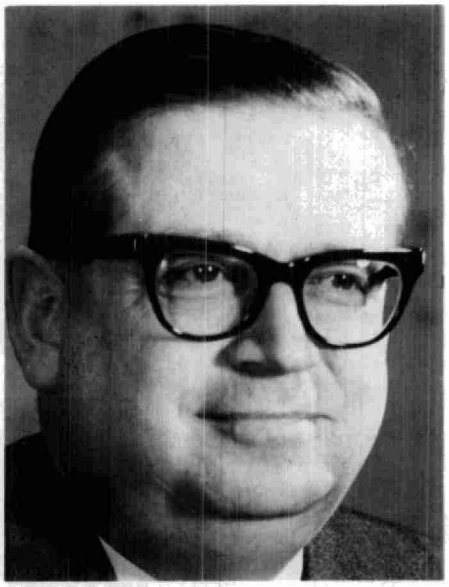
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D. S. Caverly,
Assistant Deputy Minister,
Ministry of the Environment.

Chairman,
Ontario Industrial Waste
Conference Committee.

I am pleased to present to you the Proceedings of our 1973 Ontario Industrial Waste Conference - our 20th Conference, and again a successful one. Contrary to the trend in recent years, there was a drop in attendance noted, probably attributable to the fact of another two conferences being held simultaneously in Toronto on associated topics. For the first time in the history of these Conferences, this year's program had an all-Canadian content, with more emphasis placed on the implementation side of waste treatment, which I believe was very well-received. Developments in the many spheres of pollution control are ever-changing and we must strive to keep abreast, and ahead, of these in order to achieve our desired objectives.

Also for the first time this year, it was decided to present a "wrap-up" of the Conference, having a long-standing delegate to our Conferences expressing his views on the content and presentation of this year's papers. I'm sure this will provide food for thought in the interests of pollution control generally.

If you have any questions in regard to these Conferences or on the Proceedings in general, please direct

them to Mr. Len Tobias, Secretary, OIW Conference Committee, Ministry of the Environment, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5.

The enclosed volume will, I know, provide you with an extremely useful reference, and I trust we may see you next year at our 21st Conference.

Conference Chairman.

DR. JUDY'S PAPER

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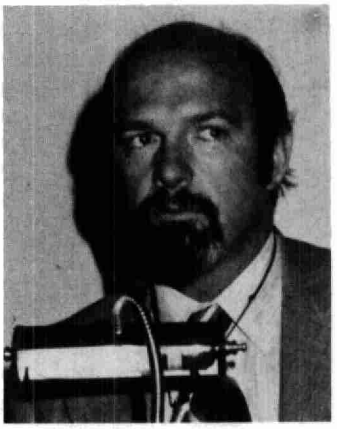
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EVALUATING ALTERNATIVE INSTRUMENTS OF WATER QUALITY MANAGEMENT

BY

DR. R. W. JUDY,
CHAIRMAN

SDL INSTITUTE,
TORONTO, ONTARIO.



R. W. Judy

0. INTRODUCTION

This paper presents some results of a comparative study of Water Management Policy in various European and North American jurisdictions. Its major purpose is to report and evaluate actual experience with policy "instruments".

The task of water management is made more difficult by the absence of a well-tested kit of management instruments. What are the instruments that can be used? How do or might they operate? What powers do they require? What problems of implementation, administration and enforcement do they pose? What are their costs, direct and indirect? How effective are they? These simple questions surely come immediately to the mind of the competent authorities

in every agency charged with the responsibility for exercising control of water discharge and abstraction. Unfortunately, there is little readily available literature that describes or, much less, evaluates the alternative instruments. The result is that each water management agency must improvise without sufficient information about which instruments are good, bad or indifferent.

The first part of the problem then, is that policy-makers wishing to implement or revise a water management program confront a paucity of useful, descriptive and evaluative material on the available instruments that they might employ.

The second part of the problem is that too little evaluation is underway of the instruments presently in use. Without such evaluation, neither policy-makers nor the public can know whether society's investment in water management is providing the greatest possible return - or none at all. A control system without feedback is no control system at all. The consequence of this lack of "feedback" is that a country may continue for many years to spend large sums of money with very little effect - or conversely, to ignore a particularly effective instrument because its effectiveness goes unrecognised.

1. OBJECTIVES IN WATER QUALITY MANAGEMENT: THE ROLE OF AMBIENT WATER QUALITY STANDARDS

Governments typically state the goals of water management in rather broad and sweeping language. Such objectives as the "encouragement of productive and enjoyable harmony between man and his environment" provide little guidance, however, to the practical business of water quality management. Much more specific and tangible targets are required as guides to action and measures of management success. Ambient water quality standards have been used in several countries as such concrete targets.

In theory, ambient water quality should be established so as to maximise the present value of a stream of net social benefits, that is, the difference between the streams of discounted social benefits and discounted social costs. But this is hardly an operational guide for action. The difficulties in fully calculating social costs are substantial and there are even greater difficulties associated with estimating social benefits.

Many of the benefits from water quality improvement are difficult or impossible to measure in monetary terms. It is correspondingly difficult, therefore, to reduce them to the same units that measure cost. Some progress has been made in quantifying recreation benefits but the aesthetic benefits and long-term ecological benefits of clean water are not likely to be as easy to measure. [1] The problems in quantifying social benefits are two:

(1) People have insufficient understanding and information about the physical, biological and social processes affected by water to be able to deduce the consequences of various levels of its quality;

(2) Even if they knew the consequences, they don't know how to express a value for many of them.

These conceptual and empirical difficulties involved in determining "optimal" ambient water quality objectives are not the only reasons why the theoretically perfect solution should not be expected. The choice of such an objective is, in effect, an allocation of costs and benefits among various groups who use, or would like to use, the water body for different purposes (e.g., recreation, fisheries, waste disposal, etc.). It is, in other words, laden with distributional consequences. Value judgements about the relative social desirability of different distributional outcomes cannot be made on a scientific or technocratic basis. [2]

The issue of how much to spend (in terms of other goods and services foregone) on the provision of various water uses through improvement of water quality is a social issue and the trade-offs should be made by society. Which subset of citizens and groups comprising society should be heard or what weights should be accorded them cannot be stated as a general rule.

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[1] Davis, R.K., The Range of Choice in Water Management: A Study of Dissolved Oxygen in the Potomac Estuary, Johns Hopkins Press for R.F.F.,Inc., Washington, 1968, pages 175-211.

[2] Royal Commission on Environmental Pollution, First Report, HMSO, London, February, 1971, page 7.

The institutional and procedural arrangements for posing and resolving this social issue are poorly developed everywhere; some jurisdictions are worse off than others.

The French "Comite de Bassin" and the Members of the British River Authorities consist largely of traditional water users (abstractors and dischargers). The Province of Ontario lacks explicit stream-by-stream ambient standards but their informal equivalents are set by technical officials within the Ministry of the Environment.

The Canada Water Act makes some provision for broader participation by suggesting that the water management agency should air its suggested standards and program at public hearings. Hearings are a step in the right direction but it may be argued that some attempt should be made to solicit public participation on an even broader basis within the region, for those who are moved to attend public hearings are not always completely representative of the water-using public at large. [3] It seems in any case, that a water management agency whose controlling board was dominated by municipal and industrial water users and effluent dischargers would be too narrow and biased a body to make such a decision by itself.

Whatever means is used to solve the political problem of bringing relevant interest groups into the decision-making process, the selection of ambient water quality standards should be made with the best available information on the probable costs and benefits of alternative water quality objectives. There are severe limits to this approach, however, particularly when water quality management efforts are first getting underway, there will inevitably be an amount of arbitrariness involved in the selection of ambient water objectives. This is hardly a disabling criticism.

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[3] For an excellent discussion on public attitudes to water resource use and on the public decision making process see Fox, I.K., "Policy Problems in the Field of Water Resources", Kneese, A.V. and S.C. Smith; Water Research, Johns Hopkins Press for Resources for the Future Inc., Washington, 1966. See also, Burton, Ian; "Water Management and the Environment", OECD, NR/ENV/72.20, April, 1972.

1.1. Actual Experience with Water Quality Standards

1.1.1. Ambient Water Quality Standards in the United States

A system of federal-provincial ambient water quality standards was initiated by the Federal Water Quality Act of 1965. Many criticisms have been made of these standards. Conservationists have complained that the standards are insufficiently stringent. State water pollution control officials have complained of their difficulty in enforcing effluent restrictions that are more rigorous than required to meet federally approved ambient quality standards. [4] Others believe the standards are too stringent. The most serious criticism, however, has been that the ambient water quality objectives or standards are unenforceable. The basic reason for this difficulty is that the Water Quality Act of 1965 made violation of the ambient standard the prosecutable act, not the discharge of effluent. When many dischargers are pouring effluent into a stream, who should be prosecuted if the ambient quality of the receiving water falls below the standard?

Disappointment about the unenforcibility of ambient quality standards has led to great disillusionment with such standards by many people in the United States. Some have argued that standards should be entirely discontinued. Such disillusionment with and readiness to scrap ambient water quality standards reflects an unsophisticated understanding of the difference between objectives and a means of achieving objectives.

Ambient water quality objectives cannot and should not be expected to be the whole answer to water quality management. They are, by their nature, unenforceable. They should not be used as the instruments of enforcement. They are objectives. They establish the targets and goals to which the

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[4] Statements of Louis S. Clapper, Director of Conservation for the National Wildlife Federation, and Kerry W. Mulligan, Chairman of the California Water Resources Control Board, Hearings of the Sub-Committee on Air and Water Pollution of the Committee on Public Works, U.S.Senate, 92nd Congress, 1st Session, 1971, pages 591, 683.

water management activities of the water body should aspire. The set of measures chosen to achieve the objective may consist of several different instruments, e.g., regulatory instruments such as effluent standards, economic instruments such as effluent charges, or collective activities such as the construction and operation of public waste treatment facilities, low flow augmentation, etc.

Other deficiencies of the U.S.federal program of ambient water quality standards, have to do with the guidelines used by the Federal Government in reviewing and improving the standards set by the States. The requirements that new industrial projects and developments should be designed so as to "provide the highest and best degree of waste treatment available under existing technology", that all wastes must receive the "best practicable treatment" and that the standards must be "feasible and achievable" and meet the consideration of "reasonableness" detracted substantially from the viability of the federal program.

In the first place, the terms "highest and best degree of waste treatment available under existing technology" and "best practicable treatment" are ill-defined concepts. There is no objective measure of what the "best existing" or "best practicable" treatment is. The latter concept was interpreted to mean secondary waste removal in sewage treatment and its "equivalent" in industrial waste treatment. Lacking any objective definition, these requirements open the door to subjective determination on an ad hoc basis and invite excessive administrative discretion with all its potential for abuse. Indeed, an admonition to establish ambient standards or management plans on the basis of these fuzzy definitions moderated by what is "feasible and achievable" was platitudinous at best, and at worst, it emasculated the entire management program.

In the second place, to specify that the "best" or "best practicable" technology, however that might be defined, should always be used, ignores the fact that treatment of this kind might contribute nothing to the achievement of desired ambient water quality. Resources expended on such treatment facilities could, in other words, be wasted in the sense that they contributed nothing towards achieving any benefits derived from water quality.

To conclude, the criticism of the U.S. Program of Ambient Water Quality Standards, frequently has been misdirected. As far as they went, the standards made a valuable contribution by encouraging the formulation of objectives, stated in terms of water quality, which were to be achieved over a specific time. It should not have been expected that ambient quality standards were the entire solution to the management problem.

1.1.1.1. Standards Set by States and Water Basin Management Agencies

Ambient water quality standards have been established by several state and inter-state water basin management committees. The Delaware River Basin Commission, for example, adopted water quality standards for the Delaware River Basin in April, 1967. The stream quality standards were linked to various uses of the water including: agricultural, industrial, public water supply, wildlife, aquatic life, recreation, navigation, and "controlled and regulated waste assimilation to the extent that such use is compatible with other uses".

Where the assimilative capacity of the water was inadequate to accommodate all those who wished to discharge wastes while at the same time maintaining the water quality standards, the Delaware River Commission allocated that capacity among dischargers. After reserving 10% of the overall assimilative capacity for future growth and as a "margin of safety", allocations were made among the dischargers on a pounds per day basis of organic waste material.

Ambient water quality objectives form an integral part of the water management programs of several other states and provinces of Canada including New York State, the Commonwealth of Pennsylvania, and California. Professionals in those jurisdictions consider ambient quality water standards to be a vital and integral part of their management programs.

1.1.2. Ambient Water Quality Standards in Canada

Ambient water quality standards have been established on international water bodies between Canada and the United States. These include the trans-boundary points of the Red River (Manitoba), the international sections of the Uranie River (Ontario) and the St.Croix River (New Brunswick) and the international sections of the Great Lakes - St.Lawrence River systems. These

ambient water quality standards, usually called water quality objectives in the publications of the International Joint Commission, are stated with varying degrees of specificity. They are in the process of becoming operational standards as the United States and Canada begin to employ various instruments to achieve them. [5]

The water quality standards on international water bodies are developed through the work of the International Joint Commission which consists of representatives from the two federal governments and from the concerned provinces and states. These objectives are recommended to the respective federal, provincial and state governments which eventually may agree on their adoption. Achievement of these water quality objectives or standards in the Great Lakes system and other trans-boundary waters has been less than satisfactory in the past. The agreement of April 15, 1972, between the United States and Canada, on the management of water quality in the Great Lakes and the connecting channels will, it is to be hoped, add strength to the clean-up programs that are now getting underway in this major basin. [6]

The provinces of Ontario, Saskatchewan and Alberta have developed water quality criteria and guidelines which apply to all streams in their respective provinces. These guidelines are used for developing effluent standards. In principle, the most restrictive use for each stream is determined and then effluent standards are set for each discharger to maintain water quality levels in the streams to support this use. Ambient water quality standards are not established on specific streams in these provinces. [7]

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[5] The Agreement between the United States of America and Canada on Great Lakes Water Quality signed by the two governments in Ottawa on April 15, 1972, specifies in Annex 1, the specific water quality objectives for the boundary waters of the Great Lakes system. This agreement presumably has the force of an international treaty and both countries are, therefore, obligated to undertake specific measures to achieve the objectives annunciated in Annex 1 of that agreement.

[6] In a memorandum of agreement dated August 13, 1971,

..... continued

The water quality objectives and guidelines developed by various Canadian provinces by and large, are not tailored to individual streams or lakes and represent general desired levels of quality rather than operational targets to be achieved within some specified period of time. Operational ambient water quality standards need to be tailored to the characteristics of specific locations on specific water bodies.

1.2. The Consequences of Having No or Ambiguous Objectives

Clear and unambiguous objectives are necessary in a good water management program; this is particularly true with respect to water quality management. When a jurisdiction attempts to mount a water quality management with no objectives, several consequences result.

Firstly, there is no criterion by which to choose from among alternative water quality management measures. It is impossible, for example, to say whether a particular effluent standard is appropriate or whether a higher degree of waste treatment is warranted. It is impossible, in short, to define a cost-effective management plan because there is no criterion of effectiveness. This may not involve a serious loss when the things that must be done are very obvious. But water quality involves very complex hydrologic economic-engineering-ecologic systems; proper management, therefore, requires objectives.

Secondly, lacking unambiguous and operational

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[6] continued
the government of Canada and the government of Ontario pledged themselves to the achievement of standards virtually identical to those embraced by the governments of Canada and the United States in their Agreement of April 15, 1972.

[7] Guidelines and Criteria for Water Quality Management in Ontario, Ontario Water Resources Commission, Toronto, June, 1970. Water Quality Criteria, Water Pollution Control Branch, Saskatchewan Water Resources Commission, Regina, June, 1970. Surface Water Quality Criteria, Environmental Health Services Division, Alberta Department of Health, Edmonton, August, 1970. Recommended Water Quality Standards, Division of Public Health Engineering, Health Branch, Department of Health Services and Hospital Insurance, Province of British Columbia, Victoria, 1969.

objectives or criteria of success, it is quite common for government agencies to cite the number of personnel, budget expenditures or other such "accomplishments" as evidence of success. The unsophisticated may take these as signs of real progress and be lulled into a false sense of complacency.

1.3. The Consequences of Having the "Wrong" Objectives

By "wrong" I mean incorrectly formulated objectives, not their stringency or lack thereof. The "right" formulation of water quality objectives ought to relate to water quality. To say that water quality objectives ought to relate to water quality sounds like a statement of the obvious - and it ought to be. Unfortunately, the objectives presented to water quality managers in some countries often are linked only tenuously to water quality. An example is an objective recently written into the new U.S.Water Quality Act of 1972. This Act posits the objective of completely eliminating the discharge of pollutants into navigable waters by 1985. Not only would this objective be extraordinarily expensive to achieve (the U.S. administration estimates the annualised costs of zero-discharge at $21.1 billion in 1981) but would contribute little or nothing of value to many of the nation's waterbodies.

The "zero-discharge" objective is only the most extreme case of the mis-specification of water quality objectives in terms of degrees of treatment or extent of waste removal. Objectives stating that all dischargers should "achieve secondary treatment or its equivalent" (U.S.A.) or "meet Royal Commission Standards"(U.K.) or "employ best practicable technology" (Canada) are all inappropriate qua objectives. [8]

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[8] It may be obviously appropriate that some dischargers should "achieve secondary treatment","meet Royal Commission Standards" or "employ best practicable technology" (whatever that may be). It may also be appropriate that some dischargers should do much more and, indeed, that some should do less - if the objective is to maximise water quality with whatever resources are available to society as a whole for this purpose.

Whatever the amount of resources that a society chooses to devote to water quality management, the pursuit of such objectives as those mentioned above is certain to result in dirtier, less desirable water than if the objectives were to be formulated in terms of water quality achieved. This point seems clear to most professional water quality managers and economists who have thought about the matter. Perception of its truth apparently is denied to many (not all) politicians, conservationists, ecology zealots and other laymen.

1.4. The Advantages of Ambient Water Quality Standards as Operational Objectives

Ambient water quality standards are objectives stated in terms of the attributes of the water. They should be linked to intended water uses by means of the criteria applicable to such uses. Perfectionists among theoretical economists may have certain reservations about them, but on balance, ambient water quality standards have impressive points in their favour; among the most significant are the following:

(1) The development of ambient water quality standards provides the occasion for focussing community attention on the problem of allocating water among alternative users.

The trade-offs between water quality and other desirable things can be addressed in a structured, rational way during the process of establishing ambient water quality standards.

The allocation of the water and its attributes among alternative users will be made in any case, even without the process of establishing ambient water quality standards. But then the allocation is done in an implicit way without the public or its representatives being given an opportunity to consider the value of water in its alternative uses.

(2) Ambient water quality standards assist in the determination of priorities.

It becomes possible to find the most efficient, cost-effective way of achieving a particular level of water quality. This helps to achieve the greatest contribution to water quality with whatever resources society makes available.

(3) Ambient water quality standards provide a means of assessing the success of water quality management activities.

Putting it quite plainly, they make it possible to determine how well the water management program is accomplishing its purposes. [9]

2. INSTRUMENTS OF WATER MANAGEMENT IN THEORY AND PRACTICE

Instruments of water management include a very broad spectrum of devices that affect water use either through direct physical action or by influencing the behaviour of water users or waste dischargers. Examples of management instruments are treatment plants, artificial aeration devices, abstraction permits, effluent standards and effluent charges.

The choice of instruments by the management agency is not a completely free one. Some of the instruments to be employed will already exist; for example, treatment plants may be operating at certain points (though their mode of operation could be changed), regulations on waste treatment or discharge may exist, or rights to particular forms of water use may have evolved and achieved recognition in law. Policy established at a higher level may direct the use of certain instruments and preclude the use of others.

Nevertheless, some room for choice almost always exists and often this is more than initially may be recognised, for structure, law and policy are not immutable. This choice should be carefully considered because instruments differ substantially in their characteristics and available evidence indicates that the more traditional ones are not immutable. This section suggests criteria for assessing the adequacy of management instruments and examines some of the control instruments in use in various countries.

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[9] For a more complete discussion of the role of ambient water quality standards in a water management program see Taylor, Anthony; A Manual for Water Quality Management Agencies, Systems Research Group, Inc., Toronto, April 1971.

2.1. Evaluation Criteria

Six criteria are suggested for evaluating control instruments. These are local efficiency, general equilibrium efficiency, equity, administrative and enforcements costs, incentives and susceptibility to evaluation.

2.1.1. Efficiency

Efficiency in water quality management requires that any level of ambient water quality be achieved at minimum social costs. At all discharge points in a particular zone, for example, the efficiency criterion requires that the costs of not discharging an additional unit of identically defined waste should be the same. If this condition is not met, it would be possible to reduce total costs while discharging the same aggregate amount of waste by requiring a discharger with low marginal abatement cost to emit somewhat less while permitting one with higher marginal abatement cost to emit an equal amount more.

Since the abatement cost functions of different dischargers vary substantially, any pollution control instrument that requires an equal decrease in waste discharge or an equal quality of discharge for all dischargers is almost certainly not efficient.

Within an individual municipality or firm, efficiency requires that each additional dollar spent on pollution reduction should be spent where it will achieve the greatest result. A firm could change the mix of output, alter the processes used, change raw materials, store wastes, treat the wastes, etc. Municipalities may have fewer options. When the efficient, least-cost combination of these methods has been found, there should be an equal incremental contribution to water quality achieved by an additional dollar spent on any of the alternatives used. Pollution control instruments that compel or bias managerial decisions toward any one method will lead to inefficiency.

Efficiency requires that the prices of goods and services should reflect the true marginal social costs of supplying them. The prices of goods and services should reflect the full costs of maintaining ambient water quality at its prescribed level.

In other words, the producer cum polluter should pay and that payment should be partially shifted on to the users of the product. If, for example, the cost of adequately controlling thermal pollution is high in electric generating stations, then the prices of electricity should reflect that fact. In addition to the production costs of labour, materials and other conventional inputs, the price of each good should reflect the costs of controlling effluent discharge necessary to achieve the relevant ambient quality standards.

The use of water quality management instruments that artificially lower marginal costs works against this efficiency objective by encouraging the consumption of the good beyond the socially desirable level. Furthermore, it distorts the structure of relative prices and adversely affects the pattern of national and international trade.

2.1.2. Equity

Equity or fairness is a concept replete with value judgements. What may seem eminently fair to one person may seem totally unjust to another.

Some structure may be introduced into the concept, however, if it can be based on values universally or commonly held. Consider the notion that "equals should be treated equally and unequals treated differently". The question that immediately arises is: "equal with respect to what?" Are all firms in the same industry equal? Are all municipalities in the same country equal? An implicit answer of "Yes" appears to underlie the use of certain water quality control instruments in some countries. Nevertheless, neither of these definitions of equality seem relevant to the business of water management.

To understand this idea of relevancy, think for a moment about a totally different area: transportation. Certainly, no-one would claim that two firms in the same industry located at vastly different distances from a vital seaport were "equal" with respect to transportation; the more remote firm would expect naturally to pay more to ship the same cargo to port. In this case, the two firms are different because the social costs of providing transportation

services are different, even though the two firms might be identical in every other respect.

Now consider two firms in the same industry whose wastes consist only of bio-degradable materials. Suppose, for the sake of argument, that these firms are identical in all respects except that:

(1) Firm 1 is located on River A with no reserve assimilative capacity, and

(2) Firm 2 is located on River B with ample assimilative capacity. *

With respect to water quality management, these two firms are quite unequal because the socially undesirable consequences from their waste disposal actions are different. They should expect, quite rightly, that the waste disposal costs associated with, say, an equal increase in their daily production would be different. Conversely, if these two firms happened to be located side by side on the same river, they should be considered equals.

Another aspect of equity concerns the transitory impact on individuals, firms and municipalities of new, more stringent water management practices. Abrupt changes in the "rules of the game" do damage to those who made location, investment or production decisions under more lenient regulatory conditions. Many people would consider such changes to be inequitable and urge some sort of a special consideration for those affected. The other side of the argument consists of two parts:

(1) The costs of doing any kind of business continually change because of changes in relative prices and all kinds of regulatory practices; land rents go up under the impact of increasing density in a region; labour costs go up because of union pressures and scarcity of certain kinds of labour services; capital costs change as a result of

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* A reserve of assimilative capacity may be said to exist when the discharge of an additional amount of BOD does not jeopardise achievement of the ambient water quality standard applicable to that river.

monetary and fiscal policy; tariffs change with the ebb and flow of protectionism. Rarely is it thought necessary to extend special consideration to the individuals, firms and municipalities that may be affected by these changes. Why should it be different in water quality management?

(2) Conservationists, particularly those who see pollution as a moral issue, have argued that society has long subsidised polluters by permitting them to escape the full social costs of their waste disposal activities; therefore, the argument goes, it is not unjust that they should now have to "pay up".

Whatever the merits of the argument that special treatment is justified for those affected by abrupt changes in the "rules of the game", the political necessities of maintaining employment and forging a coalition that will permit any kind of effective water quality management may dictate some kind of compensation to alleviate the adverse impact.

The decision about granting compensation is a political or social question. Unfortunately, the methods chosen of granting compensation frequently have adverse economic consequences, i.e., they violate criteria of efficiency, they undermine desired incentives,and they vitiate the effectiveness of the water management programs.

Different instruments of water quality management have different redistributive effects with respect to income and wealth. It may be persuasively argued that water management should not be made the servant of policies designed to affect income redistribution. Nevertheless, the different redistributive results of applying different instruments cannot be ignored. In the final analysis, these various equity considerations are issues of social choice that reflect value judgements. Basically, they are philosophical and political rather than technical or economic.

2.1.3. Administration and Enforcement: Feasibility and Costs

There may be great variation in the feasibility and cost of administering and enforcing the various water quality management instruments. Some instruments that appear at a first glance to be superb, in fact, may be virtually useless because they are not feasible or very costly from an administrative or enforcement point of view.

Administrative costs include those connected with information acquisition and dissemination as well as the technical computational and clerical activities required to effectively employ a given instrument. Enforcement includes the activities of monitoring the behaviour of dischargers, detecting violations and ensuring compliance.

2.1.4. Incentives

Incentives lie at the heart of the pollution problem. Pollution occurs in the first place because individuals, industries and municipalities lack sufficient incentive to properly control the discharge of their wastes into the environment.

Indeed, what is and what is not a waste depends strictly upon incentives; if it is more advantageous for the would-be discharger to recycle and reuse material than to throw it away, that material ceases to be a waste and becomes a valuable by-product, usable scrap or a saleable second-hand item.

Changing the incentive structure to make production and consumption activities less prone to produce waste and to discharge it into the environment is much of what pollution control is about. The rest of the job of controlling pollution consists of reducing the damages that the wastes, once discharged, do to the environment and to the people in it.

Water management instruments differ very greatly in the incentives that they provide to dischargers and to the officials of the water management authority. Some instruments, paradoxically, encourage the very behaviour that they are designed to prevent. Some provide strong motivations to acquire the services of lawyers skilled in the art of finding loopholes in legislation or in taking advantage

of ambiguous phraseology or in fighting delay actions. Still others place a premium on reaching a "warm and friendly understanding" with regulatory officials or on gaining control of the governing boards of regulatory agencies. The same instruments may provide conflicts of interest for regulatory officials and tempt them to compromise their professional ethics.

Some instruments, on the other hand, motivate dischargers to comply quickly and efficiently. It is important to know these differences. The incentive structure provided by the institutional arrangements of water quality management and by the set of management instruments chosen is one of the most important, yet least understood, attributes of a water management program.

2.1.5. Susceptibility to Evaluation

It is possible to observe the effects of some instruments; others work, as it were, in the dark - their results are never seen. If the results of applying a management instrument remain hidden, it is impossible to say how well or badly it works. The efficacy of a management instrument should be subject to evaluation. Insusceptibility to evaluation is a serious disadvantage.

2.2. Instruments that Seek to Control Through Regulation

Controls that set standards or constraints on the treatment or discharge of wastes and implement such standards by direct regulation comprise this category. There is a wide variety of such instruments in operation in various countries, some of which are described below.

2.2.1. Prohibition of Discharge. The complete prohibition of any discharge of one or several wastes.

The most obvious kind of regulation, and the one that springs first to the minds of newcomers to environmental quality management, is prohibition of discharge. This is the kind of regulation that Moses brought down from Mt.Sinai; "Thou shalt not..." Most, perhaps all countries have laws of this kind. The United States has its Refuse Act of 1899 which prohibits the discharge of any waste into navigable

waters or their tributaries; France has the laws of 28 April, 1898 and 19 December, 1917, which make similar sweeping prohibitions; Canada's Fisheries Act of 1952 as amended, makes it a criminal offence to discharge any effluent into waters "where fishing is carried on" that would be deleterious to fish.

With such very strongly worded legislation, one might ask "why is there a water pollution problem?" The answer, of course, is twofold;

(1) Complete prohibition of discharge of all discharge of all waste would entail extremely high costs.

(2) After a point, additional waste removal will produce little or no improvement in the quality of receiving water.

For particularly noxious and harmful substances, absolute prohibition is the most appropriate regulatory instrument that can be used. For the less exotic, bio-degradable wastes, absolute prohibition is normally a very poor instrument.

It is inefficient because, for the same social cost in terms of other goods and services foregone, higher environmental quality could be achieved by reallocation of resources from expenditures on discharge reduction to investment in controlling run-off from non-point sources of pollution, in-stream treatment, low-flow augmentation, etc.

From the points of view of equity, absolute prohibitions impose cost burdens on would-be dischargers far in excess of any social costs that such discharge might occasion.

However appealing may be the phraseology of sweeping prohibitions, courts in all countries have tended to look at what is "reasonable and practicable" and, in so doing, made the enforcement of absolute prohibitions a very expensive and difficult matter. This has also provided incentive to dischargers to invest in expert legal assistance in demonstrating why the application of absolute prohibitions would

be "unreasonable" rather than in investment in rational water pollution control measures.

To conclude, absolute prohibition has been ineffective as a control instrument in all countries except in those cases where it has been specifically focussed on the prohibition of toxic and other dangerous substances.

2.2.2. Discharge Permits. The prohibition of discharge except under conditions specified in a permit or licence granted (or denied) by a regulatory authority.

Many jurisdictions employ discharge permits of one description or another. There is considerable variation in their design and operation. Few of these systems have been in operation for a sufficient time to allow a full, empirical evaluation. Some evaluative comment, of a limited nature, can be provided.

2.2.2.1. Canada's National Effluent Regulation Program

At the national level, the Environmental Protection Service (EPS) of the Federal Department of the Environment has recently inaugurated a "National Effluent Regulation Program". This involves the establishment of national effluent standards based on "proven practicable technology" which are intended to provide a "uniform and equitable baseline to be applied across the country". The list of industries scheduled for regulations under this national effluent standards program is provided in Table 1.

Regulations of this type were proclaimed for the pulp and paper industry on November 2, 1971 and for the chlor-alkali plants on March 28, 1972. Table 2 displays the permitted deposits of suspended solids and BOD.

In summary, Canada's national effluent regulation program has the following characteristics:

(1) Effluent standards are developed on an industry-wide basis and stated in terms of effluent permitted per unit of output.

..... continued

TABLE 1

CANADA'S NATIONAL EFFLUENT REGULATION PROGRAM

REGULATIONS AND/OR GUIDELINES	ANTICIPATED SCHEDULE (To completion of Technical Aspects)
1. Pulp and Paper Industry Effluent Regulations and Guidelines	Promulgated
2. Chlor-alkali (Mercury) Regulations	Promulgated
3. Petroleum Refinery Effluent Regulations	February 1973 (Phase I
4. Fish Processing Plant Effluent Guidelines	February 1973
5. De-inking (Pulp and Paper) Operations Effluent Guidelines	March 1974
6. Mining Industry Effluent Regulations	
6.1 Base Metals, Guidelines	September 1973
6.2 Fuels, Guidelines	January 1974
6.3 Industrial Minerals, Guidelines	September 1974
6.4 Precious Metals, Guidelines	March 1975
6.5 Iron, Guidelines	June 1974
6.6 Pyro and Hydrometallurgy	January 1975
7. Animal Feedlot Guidelines	July 1974
8. Municipal Wastewater Effluent Guidelines	July 1974
9. Plastics Industry Effluent Regulations	November 1974
10. Steel Industry Effluent Regulations	March 1975
11. Petrochemical Industry Effluent Regulations	March 1975
12. Cadmium Using Industries, Effluent Guidelines	March 1975
13. Metal Plating Industry Effluent Regulations	June 1975
14. Effluent Regulations for Selected Toxicants	Various

Source: Program Development Branch
Water Pollution Control Directorate
Environmental Protection Service
Environment Canada, April, 1972.

TABLE 2

CANADA'S PULP AND PAPER EFFLUENT REGULATIONS

(excerpt)

SCHEDULE A

PERMITTED DEPOSITS OF TOTAL SUSPENDED SOLIDS IN THE EFFLUENT OF MILLS IN POUNDS PER TON*

Column I Component Process Category	Column II Existing Kraft, Sulphite or Semi-chemical Mill	Column III New, Expanded or Altered Kraft, Sulphite or Semi-chemical Mill	Column IV Existing Mechanical Mill	Column V New Expanded or Altered Mechanical Mill
1. Wood rewashing	5	5	5	5
2. Debarking Hydraulic Process	5	5	5	5
3. Debarking—Wet Drum Process	10	8	10	8
4. Pulping	7	5	13	10
5. Bleaching	6	4	2	2
6. Pulp Sheet Formation	2	1	5	4
7. Integrated, Single-Product Paper Making	3	2	5	4
8. Integrated, Specialty, Single-product Paper Making	6	4	10	8
9. Tissue Paper Making	15	10	20	15
10. Fine and Specialty Multi-product Paper Making	25	20	25	20
11. Cylinder Paper or Paperboard Manufacture	15	12	15	12
12. Neutral Sulphite Semi-chemical Corrugating Medium	7	7		

*"ton" means, in respect of a component process category in
(a) items 1 to 3, an oven-dry ton of wood processed without the bark,
(b) items 4 to 6, an air-dry ton of product, and
(c) items 7 to 12, a ton of product as produced.

ANNEXE A

DÉPÔTS PERMIS DE SOLIDES EN SUSPENSION DE TOUTE NATURE DANS L'EFFLUENT D'UNE FABRIQUE, EXPRIMÉS EN LIVRES PAR TONNE*

Colonne I Éléments de transformation	Colonne II Fabrique existante de pâte kraft, de pâte au bisulfite ou de pâte mi-chimique	Colonne III Fabrique nouvelle, à capacité accrue ou modifiée de pâte kraft, de de pâte au bisulfite ou de pâte mi-chimique	Colonne IV Fabrique existante de pâte mécanique	Colonne V Fabrique nouvelle, modifiée ou à capacité accrue de pâte mécanique
1. Lavage du bois	5	5	5	5
2. Écorçage—procédé hydraulique	5	5	5	5
3. Écorçage au tambour —procédé humide	10	8	10	8
4. Cuisson	7	5	13	10
5. Blanchiment	6	4	2	2
6. Transformation de la pâte en feuille	2	1	5	4
7. Fabrication intégrée d'un seul produit de papier	3	2	5	4
8. Fabrication intégrée d'un seul produit de papier à usages spéciaux	6	4	10	8
9. Fabrication de papier mousseline	15	10	20	15
10. Fabrication de papiers fins et de papiers à usages spéciaux	25	20	25	20
11. Fabrication de papier ou de carton au moyen d'une machine de forme ronde	15	12	15	12
12. Fabrication de pâte mi-chimique au sulfite neutre pour carton à onduler	7	7		

*«tonne» désigne, pour ce qui concerne un élément de transformation mentionné
a) aux articles 1 à 3, une tonne de bois écorcé transformé (sec absolu)
b) aux articles 4 à 6, une tonne de produit (sec à l'air), et
c) aux articles 7 à 12, une tonne de produit fabriqué.

SCHEDULE B

PERMITTED DEPOSITS OF OXYGEN-DEMANDING DECOMPOSIBLE ORGANIC MATTER IN POUNDS OF BOD PER AIR-DRY TON OF PRODUCT

Column I Type of Process	Column II Existing Mill	Column III New, Altered and Expanded Mill
Sulphite pulping yield of 55% or less	255	170
Sulphite pulping yield of more than 55% and less than 65%	170	115
Sulphite pulping yield of 65% or more	150	75
Sulphite bleaching (market pulp)	35	35
Kraft pulping	64	33
Kraft bleaching	27	27
Neutral Sulphite Semi-Chemical pulping	80	60

ANNEXE B

DÉPÔTS PERMIS DE MATIÈRES ORGANIQUES DÉCOMPOSABLES PAR OXYGÉNATION EN LIVRES DE DBO PAR TONNE DE PRODUIT SEC À L'AIR

Colonne I Genre de procédé	Colonne II Fabrique existante	Colonne III Fabrique nouvelle, modifiée ou à capacité accrue
Cuisson au bisulfite—rendement d'au plus 55%	255	170
Cuisson au bisulfite—rendement de plus de 55% et de moins de 65%	170	115
Cuisson au bisulfite—rendement de 65% ou plus	150	75
Blanchiment au bisulfite (pâte marchande)	35	35
Cuisson de la pâte kraft	64	33
Blanchiment de la pâte kraft	27	27
Cuisson de la pâte mi-chimique au sulfite neutre	80	60

Source: Canada Gazette, Part II, Volume 105, No. 22, November 24, 1971, p. 1889.

(2) The standards are nation-wide in scope.

(3) The standards are said to be developed in close collaboration with representatives of industry and provinces.

(4) Initially, the standards apply only to new or substantially altered plants.

(5) The standards will be applied to existing enterprises on a plant-by-plant basis to be negotiated with each firm and the province in which it is located.

It is not yet possible to give a full evaluation of the Canadian national effluent regulation program. Still, it is possible to anticipate how it will operate, at least in part.

The main official rationale for this program has been its likelihood of early effectiveness. It has been argued that the main polluters of Canada's waters are a relatively few firms in a relatively few industries. Therefore, effective direct regulations of these firms and industries would provide a quick pay-off in contrast to what could be expected from the slower process of developing comprehensive water basin plans with water quality components.

What can be said about the Canadian national effluent regulation program in terms of its own internal criterion of early effectiveness? Considerable scepticism seems warranted on this point. After about two years of operation, the program has produced regulations and guidelines for two or three industries. It would seem difficult to argue that the behaviour of any enterprises has yet been seriously affected by the regulations so far promulgated.

The main reason for this, of course, is that the regulations have been constructed with the broad participation of affected industries and provinces and have had, therefore, to be acceptable to all interests concerned. They represent a "good housekeeping standard" and impose little if any

burden beyond what would be shouldered by a well-managed institution in any case. Furthermore, they apply mainly to new and altered plants and will only begin to affect the large number of existing installations over time and so long as no serious economic interests are affected. I think that these regulations will not be very effective in reducing pollution discharge either early or late but that they may appear to the public to be so.

If the effluent regulations promulgated were stringent enough to seriously affect the industries concerned, what could be said of their efficiency properties? The answer is that they are inefficient from practically every point of view. First of all, the standards bear no relation to the quality of the receiving waters. In some cases, the standards may be insufficiently stringent to ensure tolerable ambient water quality. Because economic and demographic density varies so greatly, uniform national effluent standards are certain to produce variable ambient water quality. The costs involved in abating pollution under effluent regulations of this kind bear no relation to the benefits to be derived from enhanced water quality; therefore, they are inefficient on that count.

A second kind of inefficiency in regulations of this kind is that they affect only selected industries; the pulp and paper industry may be asked to reduce its BOD discharge but oxygen-demanding effluents from other industries, e.g., the food processing industry, either will not be regulated or will be affected only after some significant lapse of time. To be efficient, the regulatory instruments should affect all dischargers of substances likely to degrade the water.

A third, and major source of inefficiency of these regulations is that they are oriented exclusively towards treatment as an effluent control measure. The choice of treating or altering processes or changing the product's mix should be made by enterprise managements. These Canadian regulations, however, vary in their impact depending on the type of process used and the kind of final output produced. In Table 2, we see that the amount of suspended solids that a pulp mill is permitted to discharge in pulp sheet formation varies in pounds per ton of output, from 1 to 5, depending on the type of mill. The permitted deposits of BOD vary

from 33 pounds per ton of product from kraft pulping to 170 pounds per ton of product for one kind of sulphiting pulping.

Such variable regulations do nothing to encourage the management of pulp mills to choose processes less likely to be environmentally harmful. The same thing is true with respect to product mix. It is well known that the manufacture of fine and special papers produces more effluent than ordinary paper. The users of such products (e.g., fine, coloured toilet paper) should expect to pay a higher price because their production is environmentally more damaging than producing a simpler, less luxurious product. But the Canadian regulations explicitly permit the manufacturers of "fine and specialty paper" to discharge 20 pounds of suspended solids per ton of output while those engaged in "integrated, single product paper making" are constrained to discharge only 2 pounds per ton of output.

In summary, such effluent regulations get very low marks by the efficiency criterion. Even if they should happen to be effective in altering the behaviour of dischargers, any improvement in ambient water quality achieved very probably could also be achieved at substantially lower social and private costs by using other instruments.

The Canadian national effluent regulation program put a kind of equity as a major objective. An official document states that: "This approach of containing pollutants at their source conveys a sense of equity across the country by providing against the creation of 'pollution havens' in areas where economic growth might be put ahead of environmental protection." [10]

In fact, if such regulations become stringent enough actually to influence firms' behaviour they are likely to be inequitable. In the first place, they provide no way by which a community can systematically address the trade-off between environmental quality and local economic development. In the second place, they impact only the industries regulated and permit others whose discharge may cause equal or greater

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[10] Strategies for Water Pollution Control, Water Pollution Control Directorate, Environmental Protection Service, February 28, 1972, pp.4-6.

damage to escape regulation altogether. In the third place, the costs that firms are required to incur are not related to anticipated improvements in ambient water quality, much less to the probable social benefits to be realised from such improvements.

The principal incentive effect of the national effluent regulation program is likely to be to encourage firms in regulated industries to make very certain that the regulatory officials are sympathetic to their points of view. By doing this, they can hope to ensure that the regulations are applied "reasonably".

I believe that firms in a regulated industry will have incentive actually to retard the development and implementation of more advanced waste abatement technology. While this may seem counter-intuitive to the outside observer, managers of firms will quickly realise that the implementation of any advanced waste treatment or other abatement technology may become identified as the "most practicable existing" or "best available" technology and be generally required by the government regulatory agency. The industry as a whole, in other words, has incentive to persuade the regulatory agency that pollution control technology is more primitive than it really is. To do this, they must avoid putting into operation, processes which might lead to more stringent requirements across the board. We may have recently been witness to this phenomenon in the controversy over the ability of the automobile industry to comply with the stringent U.S. 1976 emissions regulations.

In summary, such an effluent regulation program creates incentives which operate in exactly the opposite direction from that desired.

It is difficult to estimate the administrative costs of developing and applying effluent standards of the Canadian variety. EPS sources indicate that the time and resource commitment of Federal authorities, industry spokesmen, and provincial regulatory officials was substantial in developing the pulp and paper regulations. No more exact estimate is at present available.

Enforcement problems will not be particularly serious if the effluent standards promulgated are reasonably lax. If the standards become more stringent, enforcement will require monitoring of effluent discharge unless complete credence

is to be put in the reports submitted by firms about their own behaviour. Because firms would have little incentive to notice any breach of the required effluent standard, a comprehensive monitoring program could be necessary to ensure honesty and accuracy. Enforcement action may entail prosecution and presentation of evidence in court. Given that the amount of evidence required to convict a violator of the standards would be substantial, enforcement probably will be costly.

Evaluation of standards such as those used in the Canadian effluent regulation program is particularly difficult. Because they are not linked to ambient water quality, it is extremely difficult to say, under the best of circumstances, whether such standards are contributing to enhanced water quality. Indeed, an official of EPS acknowledged that the sole criterion of success which could be applied to the national effluent regulation program was the degree of compliance of firms with the standards. Since the standards are not linked to ambient water quality, the true success of such a program is difficult or impossible to evaluate.

The single advantage of such effluent regulations appears to be that they are simple in concept and easily grasped by all concerned. They have the advantage of seeming to be tough and effective while causing little discomfort to any industry or group of workers.

2.2.2.2. Discharge Consents in the United Kingdom (England and Wales)

In Britain, potential dischargers are required to make application to the River Authority in whose area the discharge is proposed to be made. The information required by the River Authority contain the point of discharge into the stream, the construction of the outlet, nature and composition, temperature, volume or rate of discharge of effluent and facilities for taking samples.

The Authority may refuse consent to discharge if its terms will not be met, but by law the consent "is not to be unreasonably withheld". When awarded, the consent is accompanied by "conditions" which specify the quantity and quality of effluent permitted. No uniform or general standards of effluent quality have

been prescribed by law but the recommendations of the Royal Commission of 1912 have been widely adopted by the River Authorities. [11] These recommendations specify a 5-day BOD not in excess of 20 milligrams/litre and suspended solids not in excess of 30 milligrams/litre. Figure 1 displays the effluent standards applied by the Trent River Authority. It is thought to be representative of the standards employed by other Authorities. It is important to note that ambient water quality standards are not used in England and Wales. The effluent standards, therefore, are not linked explicitly to in-stream water quality objectives.

What has been the effectiveness of the British System of Discharge Consents? We may evaluate this in terms of:

(1) Compliance with the consent conditions (effluent standards) and

(2) What has happened to the quality of receiving waters over time.

Nearly twenty years after passage of the Rivers (Prevention of Pollution) Act (1951) there remains widespread non-compliance with the consent conditions established by the River Authorities. This is particularly true with respect to the discharge of municipal sewage effluent.

In the Trent River Authority, data for which are presented in Table 3, about 55% of sewage treatment works accounting for 65% of sewage effluent were in compliance with consent conditions in 1970. This pattern would seem typical for other River Authorities.

In 1969-70, about 56% of municipal sewage authorities reporting (see Table 4) to the Institute of Municipal Treasurers, indicated that the effluent discharged by their treatment works was

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[11] In a memorandum prepared by technical advisors of the Ministry of Housing and Local Government in 1966, the Royal Commission Standards were accepted as the "norm". See Technical Problems of River Authorities and Sewage Disposal Authorities in Laying Down and Complying with Limits of Quality for Effluents more Restrictive than those of the Royal Commission, HMSO, London, 1966.

FIGURE 1

Effluent Standards of the Trent River Authority

STANDARDS APPLIED TO EFFLUENTS FOR DISCHARGES TO STREAMS

The following are the standards normally imposed by the Authority in consents under the provisions of the Rivers (Prevention of Pollution) Acts, 1951-61, for discharges of sewage or trade effluent.

Fully treated domestic sewage effluent

(a) For flows up to that obtained by the application of formula A*.

The effluent discharged to the stream shall not:-

1. have a B.O.D. (5 days) in excess of 20 mg/l;
2. contain Suspended Solids in excess of 30 mg/l;
3. exceed ..... cubic metres or litres per day under dry weather flow conditions (the flow normally being the design capacity of the sewage works).

(b) At sewage works where flows up to that obtained by the application of formula B* are given full treatment the following conditions apply when the flow arriving at the works is in excess of that obtained by the application of formula A*.

The effluent discharged to the stream shall not:-

4. have a B.O.D. (5 days) in excess of 30 mg/l;
5. contain Suspended Solids in excess of 40 mg/l;

In some instances where it is desirable to protect the quality of river water used for potable water supplies or a fishery which contains a large proportion of sewage effluent, the following condition may be imposed:-

6. the effluent discharged to the stream shall not contain ammoniacal nitrogen (as $N\dagger$ in excess of 10 mg/l. (At some sewage works the ammoniacal nitrogen concentration is limited to 5 mg/l during the (summer) months of April to September inclusive).

When the sewage contains significant quantities of trade effluent, further conditions may be imposed such as:-

The effluent discharged to the stream shall not:-

7. have a permanganate value (4 hours) in excess of 20 mg/l;
8. contain arsenic, cadmium, chromium, copper, lead, nickel and zinc, in total in excess of 1 mg/l;
9. contain uncomplexed cyanide (as CN) in excess of 0.1 mg/l;
10. when the effluent, after dilution to x times its volume with standard water of hardness 25 (or 250) mg/l, is tested by the method described in Appendix 2 of the Report of the Committee on Fish Toxicity Tests set up by the Ministry of Housing and Local Government, not more than 5 fish shall die.

Trade effluent

As well as conditions similar to those for a domestic sewage effluent containing significant quantities of trade effluent, other conditions may be imposed such as:-

The effluent discharged to the stream shall not:-

11. contain non-volatile matter extractable by light petroleum in excess of 5 mg/l;
12. have a pH value less than 5 nor greater than 9;
13. contain other specified inorganic or organic chemicals in excess of ..... mg/l;
14. have a temperature in excess of 30°C;
15. have a rate of discharge in excess of ..... litres per second.

When the trade effluent consists solely of cooling water, the conditions limit the permanganate value, the B.O.D. and Suspended Solids to not exceeding 10 mg/l. If the cooling water is abstracted from a river or canal, the conditions allow an increase of 2, 3 and 5 mg/l in the permanganate value, B.O.D. and Suspended Solids respectively on the quality of water abstracted.

Storm sewage tank effluent

16. the effluent discharged to the stream shall not contain suspended solids in excess of 150 mg/l;
17. the rate of discharge of effluent to the stream shall be limited to the amount by which the rate of flow at the storm sewage separating weir is at the time of discharge in excess of ..... litres per second (the figure obtained by the application of

formula A)* and the discharge of effluent shall take place for only so long as an overflow is occurring from the storm sewage tanks.

Storm sewage overflows on foul sewers

18. the rate of discharge of the effluent to the stream shall be limited to the amount by which the rate of flow in the outfall sewer at the storm overflow weir is, at the time of discharge, in excess of ..... litres per second (the figure obtained by the application of formula B or the carrying capacity of the sewer if this is greater)*.

Storm sewage overflows at sewage pumping stations

19. the rate of discharge of the effluent to the stream shall be limited to the amount by which the rate of flow in the sewer(s) draining to the pumping station is at the time of discharge in excess of ..... litres per second (design capacity of the pumping station).

Emergency overflows from sewage pumping stations

20. the discharge of the effluent to the stream shall be limited to an overflow from the sump when the pumping station ceases to operate due to circumstances outside the control of the Council, and it is not reasonably practicable to dispose of the sewage otherwise.

Effluent from surface water sewers

21. the effluent discharged to the stream shall consist only of surface water.

More stringent standards

Should the dilution for the effluent available in the stream be small or the use of water from the stream be such that a higher than normal standard of effluent is required, more stringent standards than those indicated above are imposed.

The following statutory statement is incorporated in all consents:-

The terms of this Consent will not, without the consent in writing of the person to whom this Consent is given (or his successor), be altered before the expiration of the period ending with the day of 19 .

FOR DISCHARGES TO UNDERGROUND STRATA

The following are the standards normally imposed by the Authority in consents under the provisions of Section 72 of the Water Resources Act, 1963, for discharges of sewage effluent from small sewage treatment plants to underground strata when there is considered to be no possibility of danger of pollution of underground water supplies.

1. The discharge shall consist only of sewage effluent.

2. The volume of effluent discharged to underground strata shall not exceed ..... litres per day.

3. No part of the sub-surface irrigation system shall be within 10 metres of any stream.

In the case of larger volumes of sewage effluent and trade effluent, if it is decided that consent can be given, more restrictive conditions controlling the quality of the discharge are generally imposed.

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* The rate of flow for discharges from storm sewage tanks and storm sewage overflows is determined by the formulae recommended in the Final Report of the Technical Committee on Storm Overflows and the Disposal of Storm Sewage. These are as follows:-

Storm sewage tank effluent - formula A

$$\frac{3PG + I + 3E}{24 \times 60 \times 60} \text{ litres per second}$$

Storm sewage overflows - formula B

$$\frac{DWF + I360P + 2E}{24 \times 60 \times 60} \text{ litres per second}$$

where DWF = dry weather flow in litres per day
P = population
G = average domestic water consumption in litres per head per day
I = infiltration water in litres per day
E = volume of industrial effluent, in litres, discharged to the sewer in 24 hours.

TABLE 3

Compliance of Sewage Treatment Works with

Effluent Standards, Trent River Authority, 1970

Description	Rivers			Canals	Total Rivers and Canals
	Non Tidal	Tidal	All Rivers		
1. Number of dischargers by effluent standards					
1.1 Royal Commission Std.					
Number Satisfactory	248	6	254	6	260
Number Unsatisfactory	196	6	202	7	209
1.2 Better than R.C. Std.					
Number Satisfactory	1	-	1	-	1
Number Unsatisfactory	1	-	1	-	1
1.3 Less than R.C. Std.					
Number Satisfactory	3	-	3	-	3
Number Unsatisfactory	9	-	9	-	9
2. Dry weather flow of sewage effluent (x 1000 gpd)					
2.1 Satisfactory	209,292	292	209,584	12,654	222,238
2.2 Unsatisfactory	118,207	299	118,506	3,618	122,124
3. Population Served by Sewage Works whose effluent is:					
3.1 Satisfactory	3,397,037	7,048	3,404,085	201,260	3,605,345
3.2 Unsatisfactory	2,028,896	7,853	2,036,749	46,378	2,083,127

Source: Trent River Authority

TABLE 4

Compliance of Municipal (1) Sewage Effluent Discharge with River Authority Consent Conditions, England and Wales, 1969-70(2)

Municipalities (1),(3) With	Complying with Standards		Not Complying with Standards	
	Number	Per Cent	Number	Per Cent
Standards More Stringent than Royal Commission	13	46	15	54
Royal Commission Standards	91	50	91	50
Standards Less Stringent than Royal Commission	17	77	5	23
Total reporting Standards and Treatment	121	56	111	44

Source: Sewage Purification and Disposal Statistics, 1969-70, the Institute of Municipal Treasurers and Accountants, London, May, 1971.

Notes: (1) Includes sewerage boards, county boroughs, non-county boroughs, urban district councils, rural district councils and the Greater London Council.

(2) Year ending March 31, 1970

(3) Including only municipalities reporting both effluent standards and quality of effluent actually discharged.

in compliance with the standards established by River Authorities. Barely half (52%) of the municipalities reporting effluent quality said that it met or exceeded Royal Commission Standards. [12]

Industrial compliance with consent conditions seems to be rather better than the record compiled by municipalities. The Trent River Authority, for example,indicates that about two-thirds of all industrial dischargers accounting for some 83% of the effluent discharged are in compliance with their consent conditions. Water purification officials in the Thames Conservancy indicated to me that some 50% of all waste dischargers in the area "usually" complied with the waste consent conditions, but that only 25% complied "virtually all the time". They indicated, however, that no particular category of discharger was particularly delinquent. Other officials elsewhere have expressed the opinion that "industry has dealt with its outstanding effluent problems more expeditiously than local authorities." [13]

The persisting non-compliance or sluggish compliance of local sewage authorities with consent conditions has various explanations. Fundamentally, the problem stems from the fact that there have been "no votes in sewage" and sewage disposal service has suffered more than other local services such as roads, public health and education, in the face of financial stringency. Another factor mitigating against the provision of adequate sewage systems is the long and hazardous gestation period required for design and approval.

On the basis of the evidence that exists, it appears that the British system of discharge

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[12] Sewage Purification and Disposal Statistics, 1969-70, the Institute of Municipal Treasurers and Accountants, London, May, 1971.

[13] Lester, W.F.; "Merits and Deficiencies of Present Water Quality Control Practice", 1969. Mr.Lester is Pollution Control and Fisheries Officer of the Trent River Authority.

licensing has indeed, made a significant impact on ambient water quality despite the fact that many dischargers still are not complying with the conditions of their consents.

With existing data, it is impossible to empirically evaluate the efficiency of the British system of discharge consent. A few conjectures, nevertheless, can be put forth. First, the link between the discharge standards and ambient water quality objectives is implicit and tenuous. This is a disadvantage that impedes the efficient allocation of resources to water pollution control activities. Furthermore, it impedes the River Authorities when they attempt to establish discharge standards that are more stringent than those of the Royal Commission. Local authorities object to having to pay the cost for achieving the higher standard and the River Authorities are unable to point to a breached or threatened ambient water quality standard to justify the requirement for higher effluent standards.

The incentive effect of the British discharge consent system differs in its application to municipalities and to industries. Municipalities generally have no enthusiasm for raising money for taxes to pay for sewage treatment works. They have incentive, therefore, to delay the construction of works urged upon them by the River Authority. Evidence indicates that the necessity for detailed approval by several agencies of government furnishes the potential for delaying action.

Industries also have an incentive to delay but it seems clear that the power of the River Authority is more respected by industry than by the municipalities.

The British discharge consent program appears to operate inequitably in several respects. Most important, however, is that some industries and municipalities comply with the conditions of their consents; others remain chronic non-compliers. An injustice is, therefore, done to those taxpayers and industrialists who conscientiously comply with the requirements of the River Authorities. The ultimate enforcement sanction against chronic non-compliance with consent conditions is, of course,

prosecution. Theoretically, prosecution or the threat of it should suffice to compel a local authority or industrialist to take the necessary steps to comply with the consent conditions. The prosecution would be in vain if there were some other result. Unfortunately, prosecution has not been an effective means of enforcement.

In fact, prosecution is used only as a last resort, and then more frequently against fishermen than against polluters. Prosecution is a last-resort measure and probably not particularly effective as an enforcement technique. In the British case, it would seem that reasoning and cajolery have persuaded a sufficient number of dischargers to partially control the volume of effluent discharged. That those parties who are unwilling to comply with the requirements of the law can chronically avoid paying the costs of pollution control and escape prosecution is a source of injustice and inefficiency.

As a concluding comment on effluent standards, I believe that they have a role to play in the operating of an effluent permit program. They have serious disadvantages, however, when used without a concomitant charging scheme.

2.3. Instruments that Seek to Control Through Economic Incentives

Economic incentives may take two forms: (1) subsidies (whether outright grants or implicitly awarded in the form of tax breaks, treatment services at less than cost, etc.), (2) charges. Only the second type will be discussed here.

Charging schemes of various kinds are in use in several countries. Among them are the following:

1. Canada. Sewer charge systems are in operation in various cities and sanitation districts. The Canada Water Act provides for effluent charges but none have been developed.

2. France. Effluent charges are used by the Basin Financial Agencies to produce revenue that helps to defray the costs of pollution abatement treatment facilities.

3. Germany. Effluent fees have long been used in the Ruhr Basin to pay for various river management facilities and services.

4. Netherlands. Effluent charges have recently been adopted to raise funds for investment in water quality management.

5. United Kingdom. Industrial users of local sewage facilities are charged by many sewage authorities.

6. United States. Many municipalities levy user charges for sewer services. The State of Vermont has an effluent charge system.

Several other countries (e.g., Czechoslovakia and Hungary) also have effluent charge systems. These various systems differ substantially in purpose, basis of charge, level of charge, disposition of proceeds and incentive effect. What follows is a case-by-case examination of several of these schemes and a comparative evaluation.

2.3.1. Sewer Charge Systems

As was stated, sewage charging schemes are used in a number of jurisdictions. It is beyond the scope of this paper to consider any significant number of them. What is of interest here is generally how they work and how effective, efficient and equitable they are. We will consider the systems used in Winnipeg and several U.S. cities.

After unsuccessful attempts to control industrial pollution by "persuasion" and licensing, Winnipeg adopted a mixed charge-licence system on January 1, 1958. The purpose of this system is stated to be "to maintain our rivers in a condition fit for all at the cheapest cost to the community as a whole". [14] Prospective dischargers of

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[14] Penman, A.; "Metropolitan Winnipeg's Industrial Waste Control Program", Water and Pollution Control, May, 1971, p.25. Most of this account is based on this source.

more than 10,000 gallons per day must apply for licences to discharge into the collective sewage system or bodies of water within or entering the Metropolitan Area. Discharge without a licence is prohibited. Licences are granted for stated quantities of "normal discharge" which is defined as effluent with:

(i) BOD not greater than 300 parts per million.

(ii) Suspended solids not more than 350 parts per million.

(iii) Not containing any significant concentrations of a number of prohibited substances. [15]

Dischargers must pay a sewer rental charge for normal waste discharges plus a surcharge based on volume and waste concentrations over and above those defined as "normal". The sewer rental charge is based on the capital and operating costs of the Winnipeg sewage treatment facilities. The cost of treating 1,000 gallons of sewage is estimated annually. The user pays a sewer rental charge based on his metered water consumption.

Table 5 lists the sewage charges now in effect in five North Carolina cities. The charges are expressed in $/1000 lbs. of BOD and suspended solids and apply only to the BOD in the waste above 250 or 300 ppm. These cities also levy charges on water used by industry; these varied from 0.22¢ to 0.425¢ per 100 cubic feet of water. [16]

In Charlotte, the charges have been in operation since 1956-57. Over the period 1956-57 to 1970-71, the BOD surcharge has risen from $41.16 to $60 and the cost of water has risen from 0.063¢ to 0.22¢ per cu.ft. During the same period, the discharge of BOD per $1000 of manufacturer's value added has

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[15] Metropolitan Corporation of Greater Winnipeg, By-Law No.1239.

[16] The following paragraphs are based on Seagraves, J.A.; "Sewer Surcharges and Their Effect on Water Use", Journal of A.W.W.A., August, 1972, pp.476-480.

TABLE 5

Surcharge Rates as of Jan. 1971

	Date Surcharge Went into Effect	Surcharges $/1,000 lb.		Waste Strength Over Which There is a Surcharge. ppm.	
		BOD	SS*	BOD	SS*
Charlotte	1956	60		250	
Durham	Jul. 1970	80		250	
Greensboro	1962	21	21	300	300
Monroe	Jan. 1970	21		250	
Winston-Salem	1970	9	9	300	300

* Suspended solids.

Source: Seagraves, J.A.; "Sewer Surcharges and Their Effect on Water Use", Journal of A.W.A.A., August, 1972, p.477.

dropped from 20.4 lbs. to 14.08 and the water consumed has dropped from 10.21 gals/$1000 value added to 7.96 gals/$1000. Durham also experienced a sharp drop in wastes discharged per $1000 of value added, from 42.71bs. of BOD in 1966 (the year previous to a warning that the surcharge was imminent) to 13.41bs. of BOD in 1970, the year the surcharge was actually implemented. In Monroe, BOD/$1000 value dropped from 34.57 in 1969-70, the year the charge began, to 20.11 in 1970-71. Similar sharp drops in response to sewage charges were recorded in Stockton, California and Richmond, Virginia.

Generalising, the responsiveness of industry to sewage charges appears to be very substantial. Obviously, if the charges are set at an extremely low level, the response is unlikely to be appreciable. But the accumulating evidence indicates very considerable responsiveness to charges and to increases in their levels.

So far as efficiency is concerned, the sewage charge gets high marks. Like a price on any other input to a manufacturing process, the charge serves to ration the limited capacity of the treatment efficiently among various would-be users.

From the equity point of view, the sewage charge is similarly satisfactory in that every discharger is faced with an identical, non-discriminatory consequence of his waste discharging behaviour.

It must be said, however, that the efficiency, equity and incentive of any charging scheme depends crucially on an administrative factor, namely, the adequacy of the reporting and surveillance of actual discharges. Only if the amount paid is directly and credibly linked with waste discharge behaviour can the incentive effect work properly. This means that the actual discharges, not estimated ones, must be reliably reported for every individual discharger. This, I repeat, is the indispensable key to any charging scheme if it is to have the desired efficiency and incentive impact on behaviour.

To see how a weak system of measuring discharges may vitiate incentives, we turn now to the French effluent charge scheme.

2.3.2. Effluent Charges in France

In France, the system of effluent charges is operated by the six River Basin Financial Agencies.

The primary purpose of these Agencies, as they presently operate, is to assist in the financing of multi-year pollution abatement and water supply plans to be implemented by municipalities and industries within the Basins. Revenue is raised by charges levied on effluent discharges and water withdrawals. The proceeds are used to contribute subsidies to the municipalities and industries who are undertaking approved pollution abatement works. The Basin Financial Agency is primarily an institution for financial redistribution.

Revenue from effluent charges is required to be used strictly for the subsidisation of pollution abatement facilities to be built during the planning period. Similarly, withdrawal charges must be used only to subsidise the development of water supply in the immediate future.

The effluent charge to be paid by dischargers is based on the quantity of effluent discharged per day as measured by the weight of suspended solids and the weight of total Oxygen Demand. Certain agencies add a term for salinity and the addition of a term to reflect thermal pollution and poisonous wastes is under study. It is the apparent intent of the authorities, however, to keep the effluent charge formula simple.

The total amount of money to be raised by an agency from effluent charges is required by law to be equal to the financial resources required to carry out the pollution control aspects of its multi-year Programme d'Intervention. The first of these programs covers the period ending in 1972-73; the first set of effluent charges were announced in late 1968 and became effective for the period 1969-1972. They are based on long-term (20 year) forecasts of pollution growth and the actions necessary to stem it. The resources required to finance the new Programmes d'Intervention are much greater than previously spent. The rate of effluent charge, consequently, will rise considerably as demonstrated in Table 6.

TABLE 6

Rates of French Effluent Charges, 1969-1976, by Basin
Applicable to Suspended Solids (SS) and Oxydizable Materials (O)*
(Francs per year per kilogram/day)

Basin	Parameter kg/day	1969	1970	1971	1972	1973	1974	1975	1976
Adour-Garonne	SS O	8.20	10.25	12.30	17.00	17.00	23.80	23.80	23.80
Artois-Picardy	SS O	4.41 7.00	7.15 11.37	11.00 17.50	11.00 17.50	11.00 17.50	14.30 22.75	14.30 22.75	16.50 26.25
Loire-Brittany	SS O	8.16	10.20	15.30	18.87	22.50	22.50	22.50	22.50
Rhine-Meuse	SS O	16.70 26.30	21.70 34.20	21.70 34.20	21.70 34.20	21.70 34.20	28.40 44.80	28.40 44.80	28.40 44.80
Rhone-Mediterranean/ Corsica	SS O	10.33 31.00	10.33 31.00	10.33 31.00	10.33 31.00	? ?	? ?	? ?	? ?
Seine-Normandy (Zone 3)	SS O	7.50	11.25	15.00	25.50	30.00	30.00	32.25	32.25

Sources: L'Eau, January, 1969, V. 56, No. 1, p. 29 and J. Picard "Analyse Sommaire des nouveaux programmes d'intervention des Agences Financières de Bassin", Unpublished, February 17, 1972.

* Excludes charges for saline pollution and tidal discharges.

The actual amount of effluent is not normally measured for each discharger. Instead, a set of conversion coefficients, applicable to each type of industry or agricultural enterprise and to each size of municipality, are applied to the level of output, number of workers or number of inhabitants to produce an estimate of suspended solids and oxygen demand produced. Such a set of coefficients is called a tableau d'estimation forfaiture (table of payment estimation). If a particular user believes that these estimates exaggerate his actual discharge, he may request an actual measurement; if his belief turns out to be correct, the Basin Financial Agency pays for the test; if he turns out to be wrong, he pays. In fact, the coefficients are set well below a realistic level and only about 1% of dischargers request that actual measurements be carried out.

Much could be said about the actual operation of the French system. It is possible to treat only a few key points here. First, the French effluent charge system, as it presently operates, is more of a taxation system than an effluent charge scheme. This is true because the amount of money paid by way of the charges to the Basin Financial Agency is not directly linked to the quantity and quality of effluent actually emitted by the discharger. I conclude, therefore, that the French effluent system now provides no incentive to the discharger to control the quantity and quality of waste actually discharged. [17] The charge is equivalent to a tax on production varying with location and type of industry.

If and when the rate of charges is raised high enough so that it becomes more expensive to pay the effluent charge than to undertake pollution abatement activities, a proper incentive will begin to operate. If that occurs, each firm will find it more profitable to improve the quality of its effluent so that its actual discharge will be better than the industry estimate contained in the tableau. It will then be motivated to request testing of its effluent. When the actual effluent of all or most dischargers comes to be

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[17] This conclusion is of less validity when the discharger is the only one of its industry in the Basin.

sampled and tested, the French effluent charge scheme should begin to work in practice as it does in theory.

On efficiency grounds, the French effluent charge system, as it now operates, scores badly because the payment made does not correspond with actual impairment of ambient water quality. Ambient water quality standards do not exist in France. Some kind of rough efficiency may result by virtue of the variation of coefficients by type of industry and product. At present, a ceiling on the payment of 2.5 per cent of value added is applied; therefore, the system subsidises pollution-intensive industries at the expense of all others. Similar remarks apply on the equity criterion.

Only on the score of administrative costs and enforceability does the French charging scheme rate well. It is easily administered because it requires so very little monitoring and policing action. It is now operating as a tax. To operate as an effluent charge with the desired efficiency, incentive and equity properties, there must be a close link between monetary payments and the quantity and quality of effluent actually discharged.

Well designed charge systems can operate very effectively as a water quality management instrument. The accumulating evidence sustains the theoretical proposition that such systems have a valid and useful role to play in most water management programs.*

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* The interested reader is referred to Development of a State Effluent Charge System, Vermont Department of Water Resources, Montpelier, Vermont, February, 1972.



THE GROWTH OF LIMITS

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Introduction

In March 1972 a report was issued by a group of specialists from M.I.T. guided by the systems analysis of James W. Forrester. This report was done under the auspices of a publically unknown organization, The Club de Rome. The founder and chairman of this 100 member international group of scientists (4 are Canadian) is Aurelio Peccei, a powerful Italian industrialist.

Shortly after, the report was published in book form, "The Limits to Growth" by Meadows and others. Since then the book has sold about 2 million copies and appeared in 20 languages. It has managed to unleash a global debate not only in the exclusive world of academe but among people of all kinds. Its impact has been felt not only in the learned journals of the intellectual enclaves but in the popular media as well. In many ways its message has become central to a world debate on the viability of economically developed states with their monolithic emphasis on growth and development.

However, before we plunge into an analysis of the content of this global debate, it is necessary to set the contemporary social scene. In particular, it is important to understand the nature of economically developed societies and the social role and relationships of the key sub-systems

- technology. Finally, one should assess the nature of certain global threats to survival, such recognition in itself being a matter of controversy.

THE TECHNOLOGICAL ORDER

What is it about this age that has created such widespread and profound unrest? New waves of disquietudes appear every day in expanding amplitudes and increasingly threaten to engulf and destroy us. War is not confined to its formal context but is open and continuous. It is in our streets, in our homes and in our hearts and minds. The barricades are being built on pastoral campus sites and the ghettos prepare for concrete jungle warfare. Affluence and poverty confront each other between citizens and countries. The generation gap cuts across all geographical, cultural and political lines. There is a world youth revolution challenging authority at every level, from home to government. Society is at war with itself.

The key to unlocking the nature of the age of unrest lies in understanding what's happening in the realm of social change. The second half of the 20th century is witnessing an unprecedented technological revolution. A science explosion has created a new technological environment which has not only transformed our physical environment, shattered traditional values, destroyed old institutions but modified the anatomy of our perception. Science and technology dominate our politics, economics and culture. At the same time, and in a large part, as a consequence of this dominance, we are witnessing a world crisis in human values manifested by the increased amplitude of unrest and violence. In this context it becomes important to understand the social system of science and technology and the professional system of its practitioners. It is equally important to examine their philosophical assumptions.

The term - the technological order - represents a sociological model of technology in the latter half of the 20th century in developed states, particularly applicable to "post-industrial" societies like the U.S.A. Other comparable terms are "technostructure" and "technosphere". Its basic characteristics are the general dominance of science and technology over politics, economics and culture; the power of technology to induce rapid social change; the characteristic exponential growth rates of science and technology and their integration with all political and economic structures, regardless of their ideological base; the anti-ecological character of technology, creating its own closed environment outside of the natural milieu and tending to perpetuate

itself as a closed system and, in effect, subverting human will, i.e. acting as if the very existence of means determine the ends of their use as well as determining that they must be used. The key words are, of course, "tend" and "as if". Otherwise we have pure technological determinism. Thus, the scientific and technological revolution has raised as a central question the nature of the human value. As the scale and scope of the machine has diminished and eroded the human role, the stress of self-conception and identity has increased. It has also created a new set of confrontations about the issues of credibility, objectivity and the value of science itself. These questions have particular relevance to the environmental issue and to perception of the threats to survival.

Thus recognition, or its lack, of global threats to survival and to their relative imminence and kind is a mix of objectivity, concern, perception, interest-vested or unvested. Within such a complex mix of attitude and understanding, it is difficult to decide on the genuine objectivity of the threat. Reputable opinions confront each other on both sides of the argument. We have, in fact, a credibility crisis, a kind not unusual over threats to human health and life. The long, great debate over the hazards of nuclear testing in the atmosphere and the shorter, but equally hot, debate over Rachel Carson's warning concerning the silencing of spring are good examples. Despite profound disagreements one discovers a small but remarkable and growing consensus among a wide variety of the most eminent, reputable, respected experts and amateurs. These people are not a majority. They do not share the identical sense of urgency or expectancy. Some hope and others despair, but they all agree that the threats are real and alarming. Many sound the necessary alarms. Others are alarmists and perhaps reduce people's capacity of response.

These are unsettling questions and again they can not yet be settled by science itself. But they are either not critical to the cause of our analysis or one can opt for some inviolability of the human spirit, not amenable to manipulation. In either case, the cause remains unchanged - that of human survival and fulfilment. Survival is easier to define than fulfilment and also the former is the precondition for the latter which will only become more fully definable in its realization. Thus, we can return to our analysis without satisfying the purists or the absolutists who could never be satisfied in any case. We can all agree that the world seems to be in a state of universal crisis and that crisis in one way or another is reducible to a crisis in human values. What is unique about this crisis is that it involves, for the first time in history, the survival of our planet.

THE QUADRILEMMA - THE WORLD'S FOUR MOST URGENT PROBLEMS

We may now identify those problems whose scope and urgency threaten the survival of civilization. We can even quantify the path of their development but as yet cannot predict accurately the timing of disaster. There are four most urgent problems in the world, a quadrilemma - population, maldistribution, nuclear power (military and civil) and pollution. These are not unrelated, but intimately connected. They all represent "Malthusian" dilemmas of uncontrolled and unlimited growth which, due to the lag of the necessary mechanisms of social control, both as institutions and belief systems, will inevitably end in disaster. They are the "bombs" (P. Ehrlich), "crashes" (G. Rattray Taylor) and "traps" (K. Boulding) leading to population explosions, ecological Armageddon, nuclear war to wars of redistribution as the have-nots fight for their share of survival. Maldistribution of consumption means maldistribution of health, wealth and justice. It exists within nations and between nations. The new communications have created the "global village" of McLuhan in the sense of instant distribution of information and rising expectancies. But expectancy has risen much faster than fulfilment and the reality of the maldistribution of consumption between economically developed nations and the developing world is such that the vast majority of people in the world can never consume at the U.S.'s or Japan's present level and can never catch up. The world's energy sources and non-renewable resources are finite and being rapidly depleted, particularly by the systems of unlimited consumption for whom controlled growth, conservation and recycling are seemingly impossible. These systems have committed repeated goofs against nature with their progress-quantity-material hang-ups. The earth is now threatened with ecocide and the system is so blind that it cannot see that the next depression will most likely be ecological, the grinding halt of industry in the face of intolerable environmental degradation. The task is to create ecological sanity and ecologize our life-styles and thus unlock ourselves from the system and revolutionize its economic and political structures. This will have to happen through a new politics using the new broadly based citizens and scientists groups already emerged or emerging throughout the world. One of their tasks is to create national policies of ecological sanity while maximizing international commitments.

Countries like Canada and the U.S.A. and all the other highly industrialized nations have consumption patterns that create what has emerged as the major dilemma in the quadrilemma, namely the growing maldistribution of consumption

between the economically developed world and the economically developing world. This was one of the pivotal issues at the U.N. Conference on the Human Environment in June, 1972. When it is understood that each American in his lifetime consumes about 50 times the energy and most major resources of that of a person in the Third World and that each Canadian consumes perhaps 30 times and that these countries continue on their manifest destiny of high exponential growth, one then realizes that it is not possible for the Third World to ever catch up and one must accept that this maldistribution dilemma cannot be resolved except by drastic revolutionary redistribution systems. Together Canada and the U.S.A. for example, with about 245 million people, are equivalent to 10 billion Third Worlders in their consumption. Thus we cannot preach what we do not practice. If we are going to have a viable population policy externally, we must have one internally. It should be noted that this maldistribution dilemma does not apply only between nations but within nations. Unlimited growth is impossible for any biological species. But we have extended the concept of limits of growth to include environmental degradation and the uncontrolled proliferation of nuclear power - civil and military - which constitutes the major military technology for global destruction. These are all types of "Malthusian" dilemmas (after Thomas Malthus), in the sense that nuclear technology is growing exponentially at rates significantly higher than the control systems - world law and order, international mediation, etc. - which would or could prevent their ultimate use and environmental degradation is outgrowing controls. We might generalize by referring to the nuclear problem in a broader sense, namely that of war itself, but it is the belief of this author that only the nuclear threat has global proportions. Moreover, nuclear technology, civil and military, constitutes the major global thrust both in terms of energy production and the military arsenals of various nations.

Environmental degradation can only continue to grow until it produces some stress in the ecosphere and this, of course, would lead to a major cataclysm of global proportions.

To return to the concept of "Malthusian" dilemmas, their essential meaning is that a real limit always exists to the growth of any population of a particular species within a habitat having ultimately finite resources of matter and energy. This is essentially the argument of the Club de Rome in its "limits of growth" concept, although arrived at through computer simulation and dynamic systems analysis. We have merely identified four such dilemmas as representing the most urgent problems that confront the world and threaten survival.

We have called this group of four most urgent problems - The Quadrilemma - after Dennis Gabor, Nobel Laureate, who, in his book, "Inventing the Future", used the term the "trilemma". We have also extended the concept of a "Malthusian" dilemma to areas other than human populations. We have extended this concept of population limits to the area of technology and the same analogy may be applied to automobile, aeroplane or weapons populations. In each case with continued growth, a point of stress is inevitably reached, either through space, energy, resource depletion or the lag of controls, i.e. the general growing disparity between population or traffic in biological and technological systems and the controls necessary to moderate, mediate and direct these populations. We have suggested this is a general characteristic of all technology, namely, the lag of controls behind traffic. In the same way the fourth dilemma in our quadrilemma is the problem of the global maldistribution of consumption between the economically developed and developing world. Here the dilemma is the difference in consumption rates and quantities and without a major redistribution coupled with a slowing-down or levelling-off in consumption in the economically developed world, is leading to a global disaster. To repeat, therefore, we have four most urgent global problems, the quadrilemma - population, nuclear proliferation, environmental degradation and maldistribution of consumption, each representing "Malthusian" dilemmas.

A key characteristic of technology, which is particularly relevant to the entire question of growth and its limits, is the rate of growth of technology itself. It is the nature of this growth, i.e. that it is exponential, that is absolutely critical to our analysis.

THE EXPONENTIAL GROWTH OF SCIENCE AND TECHNOLOGY

Science and technology are growing more rapidly, the growth in fact is accelerating more than any other aspect of human activity. Whether we select such disparate features as the number of science abstracts, the number of workers in the electronics industry, the number of patents or the number of overseas flights, this accelerated growth rate is such that all areas of science and technology are doubling about once every 10 to 15 years. In effect, if applied to the number of scientific workers, over 80 per cent of all the scientists who ever lived are alive today. Or we could say, without proof of course, that the total amount of knowledge in the areas of science and technology has doubled between 1962 and 1972 and will double again in a decade by 1982. Moreover, the rate of commercial exploitation of scientific discoveries is itself accelerating.

Little Science has become Big Science, institutionalized and powerful and supported in large part by the state.

Nothing is more critical to a true insight into the nature and urgency of the global threats to survival than understanding the meaning of exponential growth, a general characteristic of the way viable areas of science and technology are growing. Only one other area of human activity rivals this rate of accelerated growth and this is the explosion of concern, commitment and association all over the world about the large-scale threats to survival. It is also the characteristic way of growing of all biological species including human population, but at lower rates. And, finally, it is the way of growing of capital invested at compound interest. Thus, understanding the nature of the exponential growth of science and technology provides a key to some of the essential characteristics of the present crisis.

This growth of science and technology is in itself a revealing characteristic analogous in significance and form to the growth of biological species. Derek J. de Solla Price, an historian of science at Yale, was one of the first scholars to measure and assess the significance of the growth of science. What is unexpected about this growth is the rate and nature of it. While other areas of human social activity grow in this way, none seem to attain the same rate. In technical language the growth of science is exponential and this is also true of technology. The simplest way to conceive of this way of growing is that it is characterized by constant doubling periods. Derek de Solla Price discovered that the number of scientists, the quantity of their communications, the amount of their research, etc. were all growing at such a rate as to have constant doubling period of 10 to 15 years. In some cases these growths had begun in the 17th century at the beginning of the Scientific Revolution and have continued in the same way to the present time. The significance of this way of growing is best understood by the fact that the most immediate current doubling period, while very short, i.e. 10 to 15 years, represents a growth equal to the total growth of the past. In the case of energy, it means that in the last 10 years, the U.S.A. used as much energy as it had used up to 1962 and that by 1982 this energy consumption will double again. This large-scale growth, in part, led Solla Price to coin the phrase "Big Science" for contemporary science, representing the socialization and institutionalization of science as well as its scale of activity rather than the earlier form of science "Little Science", a product largely of amateurs and individuals and on a small scale. There is always an innate deception to exponential growth.

As explained earlier, both direct and derivative aspects of science and technology are growing at this high rate exponential growth. Thus, the number of science abstracts, the number of workers in the electronics industry, resource and energy consumption, the number of patents, the number of overseas flights, support systems in the automobile industry, etc. are all growing exponentially at a rate such that they are all doubling about once every 10 to 15 years.

There is a simple riddle which illustrates the nature of exponential growth and its unexpected way of growing at increased absolute quantities in the same time period. The first concerns a bacterial colony in a litre container. If there are seven bacteria to begin with and they are doubling every minute, it takes 40 minutes to fill the litre container. How long does it take to half-fill it? The answer, as you have probably worked out, is 39 minutes. Since it doubles every minute, it must have been half-filled at 39 minutes. The deceptive part is in the last minute. Its growth is equal to its whole life cycle of growth in the 39 minutes up to that point. The dilemma is that we do not recognize the crisis of the 39th minute. Compound interest is another example of exponential growth. If, for example, you have invested $1000.00 at 7% per year compounded annually, your investment will reach $2000.00, i.e. it will double in 10 years. Common sense might have thought that in 10 years it would only have increased by 70% but what must be understood is that you are compounding the interest, i.e. each 7% is not on the original $1000.00 but on the accrued amount. On the other hand, $1000.00 invested at a fixed interest per year, i.e. 7% per year but not compounded, will only amount to $1700.00 in 10 years.

For those interested in the mathematical form of these curves, a convenient form is $Q=ae^{bT}$ where Q is the quantity, e is the Napierian log base, T the time elapsed, and a and b constants, characteristic of some particular exponential curve.

The Growth of Limits

In view of the nature of exponential growth we can now begin to assess some of the content of the debate on "limits to growth". We have preferred to refer to the concept that societies must evolve from exponential modes to steady-state conditions as the growth of limits. On the other hand, the decision to undertake such an evolution is itself revolutionary. Not only the results of the Club de Rome's computer simulation study, but ecological insights,

suggest such a steady-state economic model is the only one with long-term stability. All traditional growth models are essentially suicidal in the short- or long-term.

In part, the problem of those who support a blind faith in the power of technology to extend the limits of growth arises out of the natural system of inter-corporate, inter-regional and international competition, by its nature a violation of the ecological principle of indivisibility. Any solution operating at some level of the system less than the dimension of the whole system, is doomed to failure. Jay W. Forrester of M.I.T. refers to the "counterintuitive behaviour of social systems", but this is a disagreeable term insomuch as using a human quality to describe an institution is highly questionable. As the characteristic of social systems, it seems true but the word is also unacceptable. Counter-systemic and certainly counter-productive are more accurate terms. Since the largest operational system is the planet itself, any limited system approaches are doomed to be anti-ecological. In terms of humans, the design capacity and, of course, the creative and imaginative capacity, exceeds the analytical capacity particularly in their ability to analyze a complex system of interacting factors. The work of the Club de Rome and the publications on the limits of growth should not be judged on the reliability of their predictions or even on their methods of quantifying factors or in all of their basic assumptions, but rather on the general principle they imply. We must all grow to accept these principles and such an acceptability is better described as the growth of limits because this concept does not attempt to be precise in its predictions. The howls of protest and even distress that have arisen over the Club de Rome's pronouncements are often petty and can be discounted as the last frenzied retreat of the apostles of growth, but even where the criticism is valid, it still cannot deny the general principle that we must accept limits to growth in order to survive. The questionable aspects of their methodology, quantifications, etc. do not alter this principle. Also, many of the critics use the same limited systems analysis to plot and pursue the glories of growth except their systems analysis is even more dubious and suffers from being more limited and less planetary.

It is of interest and, of course, predictable that the most vociferous protests have come from growth economists or "New Cornucopians" such as Kneese and Ridker of 'Resources for the Future' or Kaysen and Revelle from the Institute for Advanced Studies, Princeton, or Philip Abelson, editor of "Science", who is so absorbed by his view that pollution is merely poor housekeeping that he would be better employed as editor of "Good Housekeeping". Discounting the latter type

of naive criticism and equally naive "acts of faith" of the new technocrats, some of the arguments against the message of the Limits to Growth have a validity although not one of principle. The concept that the extension of productivity of land or resources is simply a matter of economic and/or technology which is the main thrust of the argument against limits, is so anti-ecological and unrealistic as to beg to be ignored. Kneese, Ridker, Kaysen, Revelle and company really believe that the limits are economic and not physical. Ken Watt has described this nonsense with a penetrating phrase "ecocidal asymptote", i.e. both resource depletion (physically) and the highest, most sophisticated form of technology for resource winning climax together in time. We have witnessed this already in the complete extinction of certain species. The same critics extol the power of invisible adjustment mechanisms that mysteriously prevent disasters. One criticism made by Kaysen to Limits of Growth is agreeable. The authors do not deal with the question of war and nuclear proliferation nor the social institutions necessary to mediate and control them.

Jay W. Forrester's work also speaks of the basic incapacity of the human mind to interpret how social systems behave or in his technical language, the human mind is not adapted to analyze the dynamic behaviour of "multi-loop nonlinear feedback systems." But obviously it is only the precise analytical system that defeats the human mind, not the analytical or imaginative insight.

There are other aspects to the concept of growth limits that are important. These have to do with energy and communication. There is a thermodynamic law of entropy which, in its simplest sense, means that in every transformation of energy some of the exchanged energy is irrecoverable as output and is lost to the environment as heat. In a popular sense we call this thermal pollution and it is always associated with energy production.

Entropy sets an inevitable and absolute limit on both energy and communication. The physical and biological environment can only absorb a certain quantity of heat before vast effects are set in motion disrupting the ecological equilibrium of the planet. But, in a somewhat similar way, an unlimited growth in communication has its own entropic contradiction best viewed as "noise", which eventually reaches a level where it drowns the entire communicating system. Alvin Weinberg has also referred to the dilemma of complexity which applies to communication. The technology of mass communication in all senses, i.e. electronic such as media, etc. but also transportation, increases faster than

the human ability to cope with it. The proliferation of sensory impressions, including human contacts, reaches a point where the amount we can perceive or understand is so small in relation to the total that the efficiency of communication is defaulted. What is true of this communication dilemma happens in overcrowded animal populations where ultimately a point is reached where communication ceases and the animals tend to become withdrawn and develop deviant and aggressive behaviour and lose social cohesiveness. Leo Szilard referred to an impending information crisis in 1929 and suggested that information would continue to increase more rapidly than human capacity to utilize it. The new technocrats feel they have an answer to these dilemmas. Fusion power is their answer to the energy question and the computer to the information and complexity problems. The problem with these "fixes" is that they ignore the ultimate absorbing limit of the earth for heat and only view energy exclusively in terms of securing all the critical raw materials a modern industrial society requires. They also ignore the problems of the computer-human interface. The computer can simply process and store far more information and cope with far more complex systems than humans, but there remains the problem ultimately of human utilization of this vastly increased store of information and enhanced complexity. We have not removed the problem. We have merely shifted it to another level.

To turn the argument against the growth optimists, we must examine their bases of prediction. When we do this we often discover a level of credibility to law as to be frightening. The case of the fossil fuels is a good example. As late as July 1972, at an international geophysical congress, we heard that the Arctic holds more oil and natural gas than total world production to this date. The Canadian Petroleum Association is particularly guilty of this, speaking of proven Canadian reserves of the order of hundreds of billions of barrels. Professor Ken North of Carleton University has skilfully exposed these false prophets of unlimited resources. The word "proven" is the critical word.

Professor North has shown that their method of prediction is based on the simplistic arithmetic of extrapolation from other areas of highly petroliferous, i.e. oil-bearing, sedimentary rock. Thus, they first compute the amount of oil discovered in East Texas, one of the most petroliferous areas in the world, and the volume of sedimentary rock in that area. Using this figure, they take the total volume of sedimentary rock in Canada and multiply

it by the figure obtained from the East Texas calculation. The fact that the volume of sedimentary rock and the amount of oil associated with it cannot be correlated is ignored. Over half the sedimentary basins in the world do not contain oil. They then compound this insult to common sense by assuming that natural gas exists in conjunction with petroleum as it does in Texas and in a specific relationship, i.e. 6000 cubic feet of gas per barrel of oil. They then compute the reserves of natural gas based on their false estimate of oil reserves. Of course, all these calculations are not only dubious but they completely ignore the extreme hazards of environmental impacts accompanying the exploration, production and transportation of all the fossil fuels - coal, oil or natural gas.

The same technocratic euphorics who have violently attacked the Limits to Growth speak, with idle and irresponsible speculation, of the huge reserves of oil in the shales of the U.S.A. and the tar sands of Alberta. The fact that to produce oil from the U.S. shales would literally destroy a large part of the natural endowments of three States and to produce it from the tar sands would involve, literally, the disposal of mountains of loose quartz grain and sulphur, is ignored.

There is still another argument directed in particular against the economists' attack on the Limits to Growth. Their main argument has been that economic laws, not ecological principles, will determine the rate of resource depletion. But actual experience simply contradicts this. The huge consuming countries like the U.S.A. become reliant on the natural resources of low consumption countries, and through their techniques of exploitation continue to consume the poorer country's resources at the same high exponential rate. Moreover, the laws of competition apply and the economically developed world competes among its members for the right to exploit the natural resources of the primary producing but less developed countries. The U.S.A. has no reason to slow down her rate of consumption of oil as long as she is depleting Venezuelan or Canadian oil reserves.

A further argument made against the prognostications of the Club de Rome is that they aggregated resources for the whole world and this distorts the real picture based on actual distribution. This would be amusing if it were not sad. For the real point is that it is not the distribution of resources that is significant, but the maldistribution of consumption. If we look at this issue from the point of view that every single person in the world is entitled to an exactly equal share of proven reserves, we see a different picture. For nickel, each person would own about 40 lbs.; for copper, each

would own about 170 lbs.; chromium - 20 lbs.; aluminum - about 900 lbs.; petroleum - 130 barrels; tungsten - less than 1 lb., etc. This is based on known or proven reserves and the present world population. The amounts are so low as to reduce the entire world to a pre-industrial stage! Even if we multiply proven reserves to pie-in-the-sky quantities, the situation is serious if we are dedicated to equality of distribution.

Professor Herman E. Daly of Louisiana State University has brilliantly castigated "growthmania" by pointing out their technique of discounting the costs of growth. This is the usual position of the GNP maniacs. But some go further than this. They take the real costs of defensive measures against the backlashes of growth and then add these to GNP as if they were benefits! Professor Daly has rightly called this "hypergrowthmania" as though one would grow to bursting and then include funeral costs as a benefit. While John K. Galbraith summed it up this way: "Everything happens as if Saint Peter, when receiving souls in heaven to send the ones to Paradise and the others to Hell, asked them only one question: 'What have you done on earth to increase the gross national product?'"

The Technological Fix

At this point, it is only fair to consider some technological "fixes" that could, in part, negate the gloomy predictions of at least the maldistribution of energy. Fission breeder reactors would extend the lifetime of uranium fuel considerably but still only for some limited time, after which the limits of further growth would apply. Similarly, but to a much greater degree, nuclear fusion power would provide a vast extension of time to energy depletion. But this, too, is a dilemma as discussed earlier, since the world cannot continue to increase energy consumption indefinitely without profound thermal effects on the ecosphere. The limits to growth are unavoidable and delay in accepting this concept will only intensify crises.

It should be noted that biological species will generally achieve a dynamic "steady-state" equilibrium, i.e. a fluctuation about some stable level in which inputs balance outputs. This is an ecological principle. It seems human populations and their social products violate this principle, or at least have done so in the past and are continuing to do so in the future. We believe such continuance is impossible and represents a "Malthusian" dilemma as described earlier. We have pointed out that many do not accept this as a dilemma but subscribe to the idea that only more technology can solve the problems created by technology and we agree that in many

cases of growth, the point of stress or crisis may be delayed by technological or social "fixes", so-called cures or adjustments. Some examples are resource substitutions, energy innovations, increased agricultural productivity, extended land use, ocean mining and farming, etc. However, not only do these "fixes" often create unexpected second-order disbenefits, but they can only delay and never deter the ultimate crisis. Moreover, the net result of such delays can often deepen the crisis when it does occur. The classical case is building more urban freeways in the hope of allaying congestion. This proves to be counterproductive, the automobile population tending to always fill the space made available for it. But the new level of congestion is a deeper crisis than the earlier one.

The concept of the technological "fix" or cure is, of course, part of the trappings of the new technocratic ideology. Often these "fixes" lead to technological backlashes of their own simply because they are violating a principle of ecology, that is, dealing with part of the system instead of the whole system. The case of the automobile is typical. The first "fix" on automobiles was designed to reduce carbon monoxide, a decision made as much from Los Angeles chauvinism as for historical or health reasons. The net effect, unfortunately, was that this "fix" led to a second-order backlash, i.e. to the increase in nitrogen oxides with the net effect of producing photochemical smog, the presently dominant Los Angeles pollution threat. Thus, each "fix" requires a "fix" and the technological order and its supporting theological followers continue to commit the same goofs against Nature. This is the technocratic trap, a dilemma of its own, the blind faith that science and technology will always discover some "fix" that allows us to extend the limits of growth and therefore to deny those very limits.

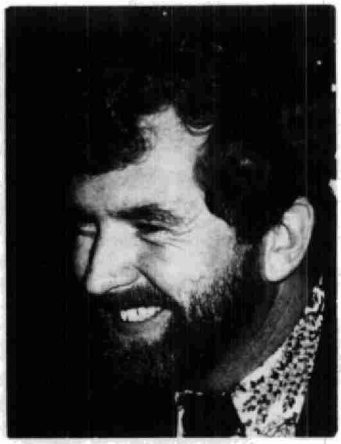
Conclusions

We will again admit that it is difficult and uncertain, if not impossible, to precisely predict when that limit will be reached in time or space but it is the principle rather than the precision that is significant. And also, it is here where values once again intervene. Concern for the future is a basic human value. Such concern means we recognize the limits of growth and act in such a way now in the present to preserve that future. Thus, for each of our four most urgent global problems, the answer is accepting <u>now</u>, before it is too late, that there is a limit to growth.

The net result of the work of the Club de Rome and the earlier critiques of "conventional" growth economics (post-Keynesian) has led to a slow but searching examination of alternative systems. Unfortunately, like many terms, the word "spaceship" suffers from semantic erosion, the pollution of language due to overuse of the term and under-examination of the concept. Nevertheless, "zero growth" or "no-growth" economics accompanied by maximum recycling of materials and zero population growth, product durability and biodegradability, decentralization, etc. is the ultimate solution for survival. However, without a radical redistribution of resources, the elimination of war and the threat of war and global resource and environmental management, neither the rich nor the poor nations will find the concept of "zero growth" acceptable. Elizabeth Mann Borgese of the Center for the Study of Democratic Institutions has prepared a draft plan for an International Earth Resource Management Organization (IERMO) to carry out the various stages to achieve global stability, financed by a contribution of 1% of the world's GNP and the massive elimination of armaments expenditures. As we have seen, this bandwagon reached the United Nations meeting in Stockholm but this is a kind of dream we must make into a reality if we are to survive; the charge of fantasy or naiveté is tolerable against the opposing charge of global suicide.



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COLD WEATHER OPERATION OF MECHANICALLY AERATED LAGOONS

BY

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INTRODUCTION

Mechanically aerated lagoons have become widely accepted as one of the most economical forms of treatment for large volumes of biologically degradable wastes. When proposed for the treatment of Pulp and Paper mill effluents in Canada, however, consideration must be given by the designer to the extreme climatic conditions under which they may be expected to operate. Fig. #1 illustrates the location of mills in Canada and northern U.S.A. with respect to the January isotherm of 20°F.

Since little published data was available on the effects of cold weather on the full scale operation of mechanically aerated lagoons, T. W. Beak Consultants Limited were commissioned by the Canadian Government to undertake a comprehensive study of three 5-day aerated lagoons operating on kraft mill effluent in Western Canada. These were:

1. North Western Pulp & Power Limited - (NWP&P)
   Hinton, Alberta.

2. MacMillan Bloedel Limited - (ALPULP)
   Alberni Pulp & Paper Division,
   Port Alberni, British Columbia.

3. Erocan Pulp & Paper Company Limited - (EUROCAN)
Kitimat, British Columbia.

The overall project involved the study of BOD loadings and HP requirements, the effects of nutrient addition and pH levels, as well as the importance of lagoon shapes, aerator spacing and quiescent zones. Of particular interest for Canadian applications are the effects of temperature on the biological degradation process and the mechanism for predicting temperature levels in such lagoons.

TREATMENT SYSTEMS

The NWP&P mill, situated in Hinton, Alberta, on the Athabasca River, produces approximately 600 TPD of fully bleached kraft pulp utilizing a six stage bleaching sequence.

Fig. #2 illustrates the waste treatment system, which was designed to treat the total pulp mill and woodroom effluents except the bleach plant acid waste. In addition to the mill waste, municipal sewage from the town of Hinton is also treated in the aerated lagoon.

The waste streams are directed to a 200 foot diameter primary clarifier and adjusted to pH7 immediately prior to the aerated lagoon.

The U-shaped aerated lagoon is divided into two sections; an aeration zone and a quiescent zone. The aerated section, with a surface area of approximately 10 acres and an operating depth of about 21 feet provides a retention time of three and one-half days at an average waste flow rate of 18 USMGD. Fourteen, 50-horsepower, floating, high-speed mechanical aerators, spaced throughout the aerated section provide aeration and mixing. The quiescent section of the lagoon has a surface area of about 10 acres and an average depth of about 6 feet providing a retention time of about one and one-half days. The treated waste combines with the untreated acid waste and is discharged into the Athabasca River through a submerged diffuser.

The ALPULP mill, situated in Port Alberni, B.C., at the head of Alberni Inlet, is an integrated mill complex producing approximately 900 tons per day of kraft pulp and 1000 TPD of groundwood. About 300 TPD of the kraft pulp is bleached. Fig. #3 illustrates the waste water treatment facilities. These were designed to process an average flow of 23 USMGD which contain approximately 85% of the total volatile suspended solids and 60% of the BOD_5 produced by the mill.

Mill effluents receive primary treatment in a 200' diameter clarifier while woodroom wastes are treated separately in an 80' diameter clarifier. The aerated lagoon has a surface area of

approximately 35 acres and an operating depth of about 13.5 feet, with a mean residence time of 5.5 days. Thirteen, 75 horsepower floating high-speed mechanical aerators and one 50-horsepower floating, low-speed mechanical aerator, are spaced throughout the lagoon to provide aeration and mixing. At the lagoon inlet the aerators are relatively closely spaced in order to disperse the influent rapidly and to supply oxygen to satisfy the higher demand of the waste, whereas the aerators near the outlet of the lagoon are more widely spaced because of the lower oxygen demand in this region. The wider spacing also provides quiescent zones for sedimentation of any settleable material before the waste is discharged from the lagoon.

The EUROCAN mill, situated in Kitimat, B.C., on the Kitimat River, consists of an unbleached kraft mill producing linerboard, paper and pulp, and a sawmill. The mill, with a design production rate of 915 TPD of kraft pulp and 130,000 Mfbm/A of sawn lumber, was brought on-stream in early October, 1970. The treatment facilities (illustrated in Fig. #4) are designed to treat the total effluent from the pulp mill and woodmill. Waste streams likely to have a high solids but low chemical content, are collected in a general sewer and settled in a 100 foot diameter primary clarifier.

Effluents likely to have a high chemical content, including wastes from the digester area, water treatment, chemical recovery and recausticizing areas of the mill are collected in a toxic sewer which bypasses the primary clarifier. In the event of an upset or chemical spill in the mill, the toxic sewer flow is automatically diverted to a spill basin.

The aerated lagoon has a surface area of approximately 23 acres, an operating depth of 13.5 feet, and a retention time of five days at the average waste flow rate of 20 USMGD. Nine, 100 horsepower floating low-speed mechanical aerators spaced evenly throughout the lagoon provide aeration and mixing. A wooden dike, about 150 feet from the side of the lagoon, creates a quiescent zone before the outlet where any settleable material is removed. The treated effluent flows by gravity to a submerged diffuser in the Kitimat River.

TEMPERATURE EFFECTS ON BOD REMOVAL

During the study period, the normal seasonal temperature variations of the waste entering the aerated lagoons were in the order of 36°C to 27°C for summer and winter conditions respectively. Seasonal ambient temperature variations were from +20°C to -20°C. These conditions resulted in mean lagoon temperatures of about 30°C in summer and about 16.5°C in winter. Typical winter operating performance for the three mills is summarized on Fig. #5.

The temperature effects on the BOD_5 removal for the five-day lagoons studied have been summarized on Slide #6. The data points shown were the average of five consecutive daily composite samples.

The effects of the mean lagoon temperature were somewhat more pronounced in the NWP&P lagoon. In the range of 20°C to 30°C, the BOD_5 removal efficiency was increased about 16 percentage points at NWP&P, while the increase was only about 10 percentage points at ALPULP and EUROCAN. The increased temperature sensitivity and lower BOD_5 removal efficiency at NWP&P could be the result of oxygen deficiency. The NWP&P lagoon was "overloaded" in terms of oxygen transfer capacity and the treatment was limited by the lack of any residual dissolved oxygen concentration in parts of the lagoon. The other two systems operated with a residual D.O. of from about 2 ppm at ALPULP to as great as 6 ppm at EUROCAN.

It should be noted that the trends seen in Figure 6 are general indicators of temperature dependence only as no consideration has been given to variations in BOD_5 removal with respect to differences in the overall mixing characteristics of each lagoon or to fluctuations in the BOD_5 loading on the lagoons.

Figure 6 also includes the result of batch treatability studies on effluent from the 3 plants and Figure 7 expresses these results separately in terms of the first order BOD removal rate constant (K).

HEAT LOSS CALCULATIONS

During the study period, the extreme temperatures of the waste entering the aerated lagoons ranged from 38°C to 15°C, whereas the effluent temperature extremes varied from 31°C to 10°C. The temperature decrease through the three five-day aerated lagoons (influent minus effluent temperature) is shown in Figure 8 plotted against the ambient air temperature. Quite naturally the maximum decrease in waste temperature is associated with lower ambient air temperatures. The maximum observed temperature loss through the five-day lagoons was about 16°C at an ambient temperature of minus 30°C (minus 22°F). The data are average values taken over a four-day period and are quite scattered due to a number of factors affecting heat losses that were not accounted for. These variables include wind velocity, relative humidity, solar radiation, foam cover over the lagoon, and the surface area increase due to aerator turbulence.

Figure 9 indicates that the temperature decrease is more closely related to the difference between the mean lagoon temperature and the ambient air temperature. If the heat loss is mainly through the lagoon surface, then the heat loss will be proportional to the air-liquid temperature differential and the surface area and can be expressed by the formula (Figure 10):

$$(T_i - T_e)\ Q = fA\ (T_m - T_a)$$

where: T_i = influent temperature

T_e = effluent temperature

T_m = mean lagoon temperature

T_a = ambient air temperature

A = lagoon surface area in square feet

Q = waste flow rate in million gallons (US) per day and

f = proportionality factor or overall heat transfer coefficient.

At NWP&P and ALPULP, which have large length:width ratios and therefore approach plug flow mixing behaviour, there is a linear temperature decrease through the five-day lagoons, and hence the mean lagoon temperature (T_m) can be calculated as the arithmetic mean between the waste temperature at the inlet of the lagoon (T_i) and the lagoon effluent temperature (T_e). In the well-mixed lagoon, such as EUROCAN, the mean lagoon temperature (T_m) is the same as the effluent temperature (T_e) and therefore the equation can be expressed:

$$T_e = \frac{fAT_a + QT_i}{fA + Q}$$

Upon examining this equation, the general response of the system may be perceived. As the waste throughput rate (Q) increases resulting in a shorter residence time, the second term in both the numerator and denominator tends to predominate. The equation then predicts less temperature loss because the terms involving surface area and ambient temperature become less important. On the other hand, if the waste throughput rate (Q) is decreased resulting in a longer residence time, the first term in both the numerator and denominator tends to predominate. Then the effluent temperature (T_e) approaches the ambient temperature (T_a). Therefore, for winter operating conditions when it is desirable to maintain as high a temperature as possible in the aerated lagoon, it is necessary to keep the first terms in both the numerator and denominator small with respect to the second terms. This may be done by minimizing the surface area (A) for a given system. This is, of course, exactly what common sense would tell us to expect.

The foregoing relationships assume that the major heat loss is through the surface of the lagoon. Temperature measurements near the surface of the lagoons were generally found to be 1.0 to 1.5°C less than the waste temperature at a depth of ten feet, supporting the contention that most of the heat loss occurs at the surface by radiation and convection to the atmosphere. Preliminary calculation also indicated that the heat loss to the ground was small and would account for only 5 to 10 percent of the total loss from the lagoon.

On Fig.#11, the heat loss per unit surface area is plotted against

the air-lagoon temperature difference. From the equation in Fig. #10, the slope of the least squares straight line is the proportionality factor "f". This slope was calculated to be 8.66×10^{-6} USMGD/ft^2, with a correlation coefficient of 0.757. In comparison, Eckenfelder has utilized a value of 12×10^{-6} for similar lagoons in the central United States.

Foam appears to have a significant effect on the overall heat transfer coefficient 'f'. Work reported by J. J. McKeown (1971) of NCASI has shown that for aerated lagoons with significant foam cover (1 inch), the value of the overall heat transfer coefficient was 4×10^{-6} USMGD/ft^2. BEAK also found that increased aeration horsepower input had no definable effect on the overall heat transfer coefficient. It is felt that the mixing action of the aerators tends to generate a stable foam and as the number of aerators increase, the foam cover also increases thereby acting as a better insulator against heat losses.

ICING ASPECTS OF MECHANICAL AERATORS

Our interest in maintaining high temperature levels in aerated lagoons is twofold:

(a) to maintain as high as possible a BOD oxidation rate as already discussed;

(b) to minimize the potential for the formation of ice on the mechanical aerators on the surface of the lagoons.

This latter icing aspect is a serious problem both to the operators of the facility and the original equipment manufacturers. I feel it generally appreciated that the development of mechanical aerators has been plagued with mechanical problems caused by excessive stresses not originally envisaged. Icing of the aerator and platforms with resultant tilting and increases in the submergence of floating units, and the impingement of falling ice on the blades of fixed mounted units simply aggravates the problem involved.

Although not covered directly by the survey let me utilize a similar mechanical aerated lagoon at Prince Albert Pulp Limited in northern Saskatchewan for illustrative purposes:

> Slide #12 is an aerial photograph of the lagoon which is about 16 feet deep, has a length to width ratio of 5:1 and a detention time of 5 days. The seven 150 HP low-speed floating aerators were spaced using a computer simulation model developed by BEAK. Winter temperatures run to well below zero degrees Fahrenheit and the effluent temperature out of the lagoon is about 50°F. In this slide a blanket of foam over the lagoon can be seen.

Slide #13 shows a view of the splash pattern created by the aerator during summer operations.

Slide #14 is a view of the same lagoon on a cold day. Notice the mist rising from the lagoon and enveloping the platform.

The ice shown here in Slide #15 is the result of mist and the splashing of effluent onto the platform.

Slide #16 which looks like some weird creature from outer space, is actually the same aerator. The slide illustrates the enormous loads which the platform has to withstand. However, even under these conditions the aerators in question operated satisfactorily.

The next three slides also refer to slow-speed floating aerators this time at EUROCAN, one of the test mills. Extremely cold weather conditions aggravated by high winds caused ice loads as high as 4000 lb on a single machine and the resultant sinking of some of the aerators!

Slide #17 illustrates the tipping of an aerator with one arm resting on the bottom as the result of icing. Corrective measures included replacement of the floats with larger ones, removal of all handrails and similar ice collecting appendages and the installation of electrical heating tape along the aerator platform arms.

The next Slide #18 shows the rescue operation of one of the EUROCAN units using a barge fitted with a hoist. This points up the necessity of being able to service aerators out in the middle of the lagoon. The following Slide #19 illustrates a platform designed by BEAK for Abitibi Corp. at Alpena, Michigan, to facilitate aerator removal from fixed platforms onto a barge.

Lest you feel that I am concentrating on floating aerators with slides such as #20 of a 25 HP floating unit in northern Michigan, let me turn to Slide #21 of a fixed aerator at the municipal plant in St. John, N.B. The aerator platforms are poorly designed in that they promote the massive accumulation of ice as shown. Similarly, this Slide #22 of a fixed mounted aerator at a phenolic resin plant north of Montreal, P.Q. Poor installation of the platform and ice buildup on the aerator shaft caused excessive vibration and subsequent damage to the unit. Slide #23 shows a close-up of

the ice cone formed. A computerized dynamic balance calculation estimated an eccentric load of 75 lb on the shaft.

Icing is partially the result of spray particles impinging on the support structure and this effect can be minimized by raising the platform well away from the splash pattern as illustrated in Slide #24. Unfortunately this approach results in excessive shaft lengths with inherent bearing problems. One solution has been the introduction of a mist or splash plate as illustrated in Slides #s 25, 26 and 27 of installation at the phenolic resin plant (Slide 25), at Orone, Maine (Slide # 26), and the municipal plant at Winnipeg, Manitoba (Slide #27). Note that this last aerator is in operation despite the build-up of ice on the platform under climatic conditions illustrated. Slide 28 illustrates more recent thinking of lowering the platform to where the platform itself acts as the splash plate. This approach can be successful provided the bottom of the platform is a smooth concrete or steel plate surface.

A recent alternate approach to the problem of icing is to eliminate the spray pattern causing it. Slide #29 illustrates a submerged impeller unit of hydrofoil section being started up after the lagoon has been frozen with approximately 1" ice cover. Slide #30 illustrates the 1" ice sheet being broken while Slide #31 shows 8" thick icebergs which were frozen in the surface being discharged to the ice shelf. In this design large water volume movement replaces air-water mixing. Another manufacturer has come forward with a submerged turbine combined with air injection in which the pumping action is downward rather than upward. Both these approaches should be successful at the price of decreased oxygen transfer efficiency and an economic calculation would be required to determine their relative merit - particularly as large installations.

One final feature to be mentioned is the use of an ice guard or shaft sleeve as shown on Slide #31. This solution would certainly help obviate the problem of ice build-up on shafts as previously illustrated in Slide #22.

Based on a review of 21 mechanical aerator installations in northern United States and Canada (involving both high and low-speed units) our conclusions and recommendations are: -

1. Low lagoon temperatures ($32^{\circ}F$ - $40^{\circ}F$) in cold climatic conditions will normally result in ice accumulation on the supporting structures and hence every effort must be made to optimize the effluent temperature level by:

   (a) minimizing the surface area of the lagoon;

   (b) keeping the detention time as short as permissible to meet treatment requirements.

2. If the predicted lagoon temperatures are below $50^{\circ}F$ and the ambient temperature is below freezing for long periods of time, floating aerators are not recommended unless precautions are taken to

provide means such as chains or piles which limit the amount of submergence if it occurs.

3. Design both fixed or floating platforms with a minimum of protruding bolts, ledges, railings, etc. to minimize the opportunity of ice accumulating. Also consider the use of hollow structural members over conventional I beam or H sections even though a cost premium is involved.

4. Consider the use of heating tapes on the arms and motors of floating aerators.

5. For fixed mounted units consider the installation of splash deflector plates to lower the spray trajectory or alternatively consider lowering the platform to act as a deflector plate and take advantage of any warm air layers immediately above the water.

6. Distances between supporting piers of fixed mounted units should be great enough so that any ice accumulation falling from, or sliding down the piers, will not damage the rotating assemblies.


JANUARY ISOTHERM OF ABOUT 20°F
(AVERAGE TEMPERATURES)
1- ST. REGIS, TACOMA, WASH.
*2- MACMILLAN BLOEDEL, PORT ALBERNI, B.C.
*3- EUROCAN, KITIMAT, B.C.
4- CARIBOO, QUESNEL, B.C.
5- PROCTOR & GAMBLE, GRANDE PRAIRIE, ALTA.
*6- NORTH WESTERN, HINTON, ALTA.
7- BOISE CASCADE, INTERNATIONAL FALLS, MINN.
8- HOERNER-WALDORF, ONTONAGON, MICH.
9- ABITIBI, ALPENA, MICH.
10- DOMTAR, CORNWALL, ONT.
11- GREAT NORTHERN, MILLINOCKET, MAINE.
12- FRASER, EDMUNDSTON, N.B.
13- GEORGIA-PACIFIC, WOODLAND, MAINE.
14- CITY OF SAINT JOHN, SAINT JOHN, N.B.
15- MIRAMICHI, NEWCASTLE, N.B.
16- NOVA SCOTIA WATER RESOURCES COMMISSION, BOAT HARBOUR TREATMENT SYSTEM
*17- GOVERNMENT OF CANADA STUDY AT LOCATIONS MARKED *
0 300 600 900
SCALE: 1" = 300 MILES
BEAK DESIGNED WASTE TREATMENT SYSTEMS
BEAK
GEN-10

FIG. 1

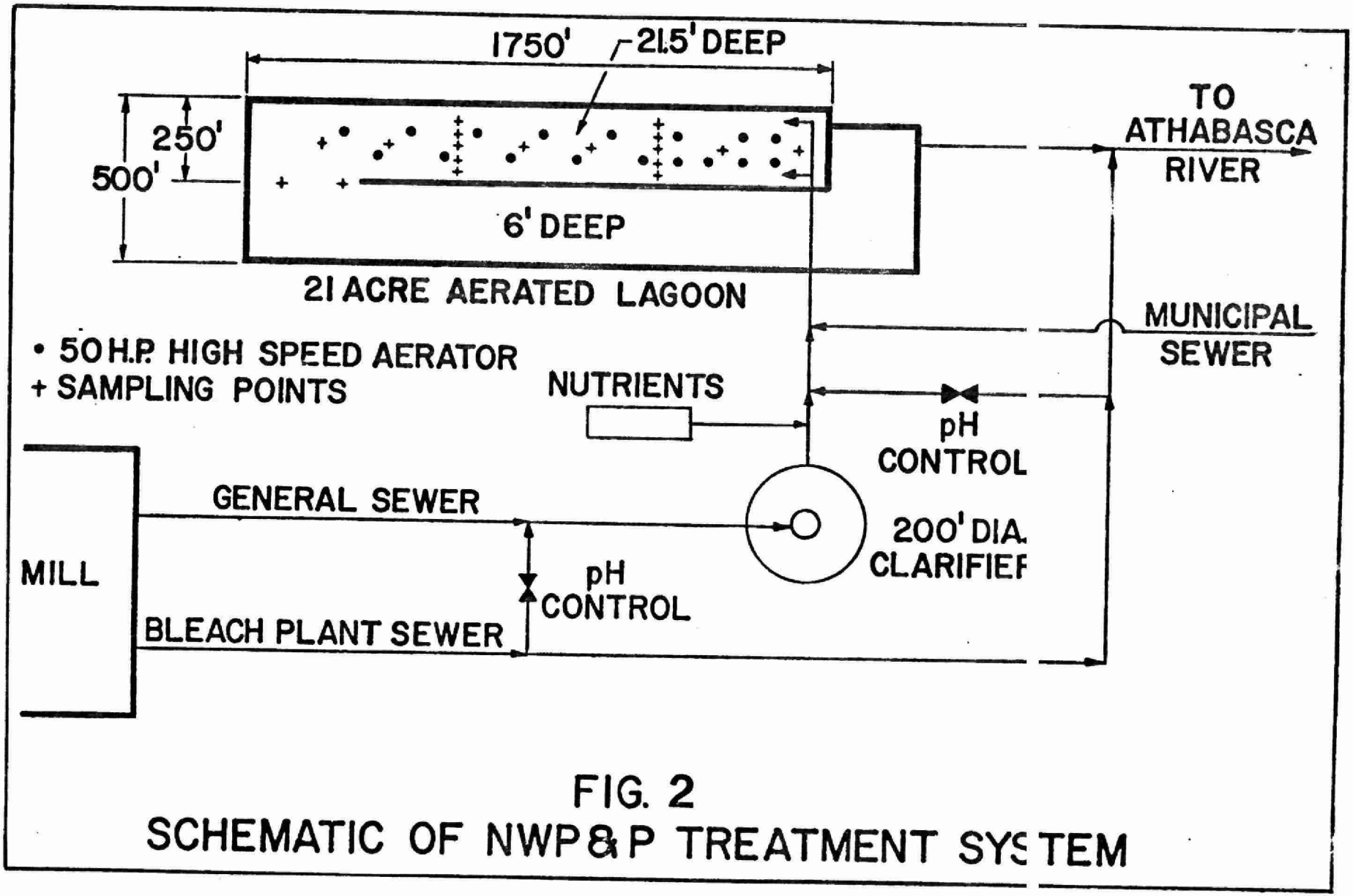


FIG. 2
SCHEMATIC OF NWP&P TREATMENT SYSTEM

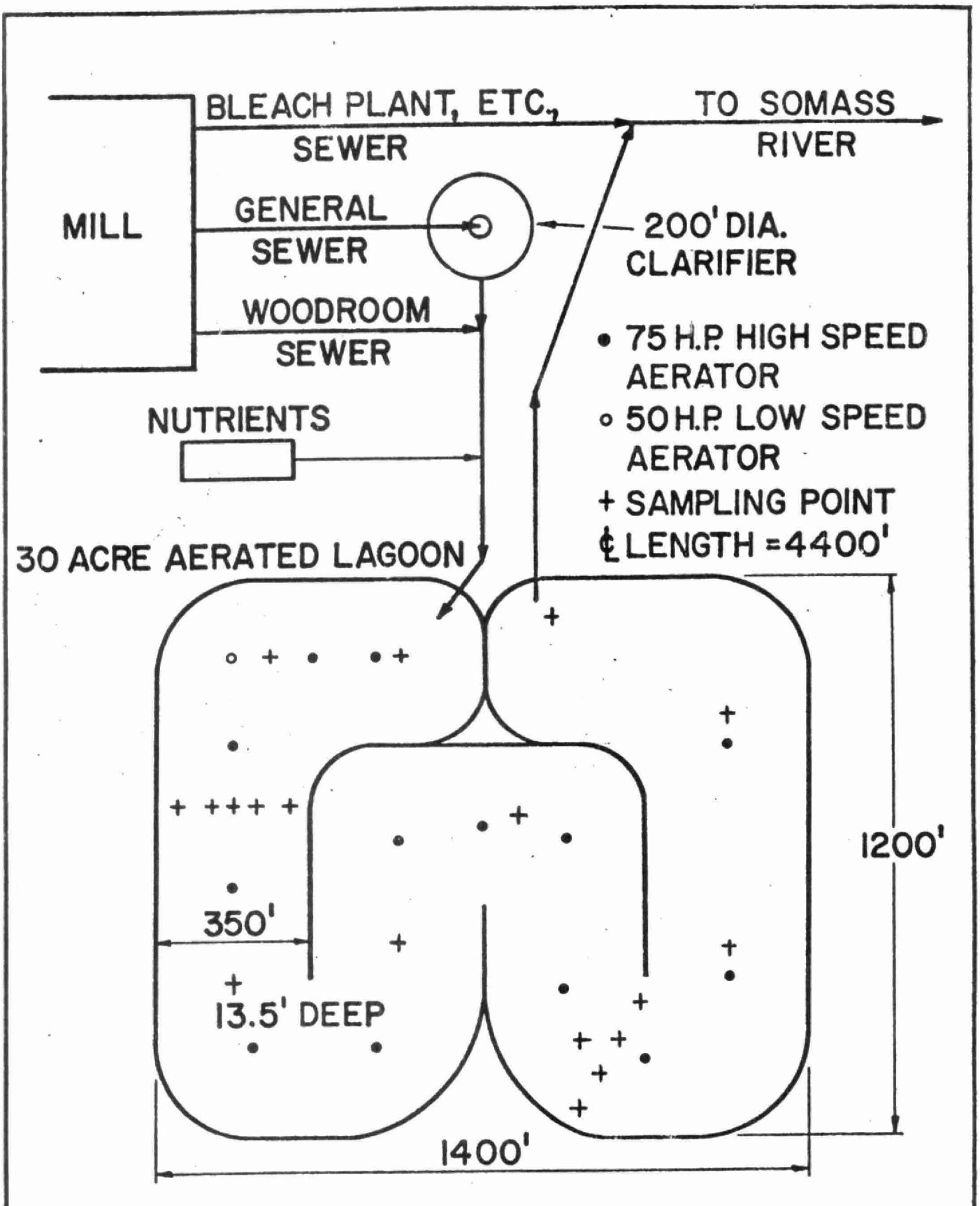


FIG. 3
SCHEMATIC OF ALPULP TREATMENT SYSTEM

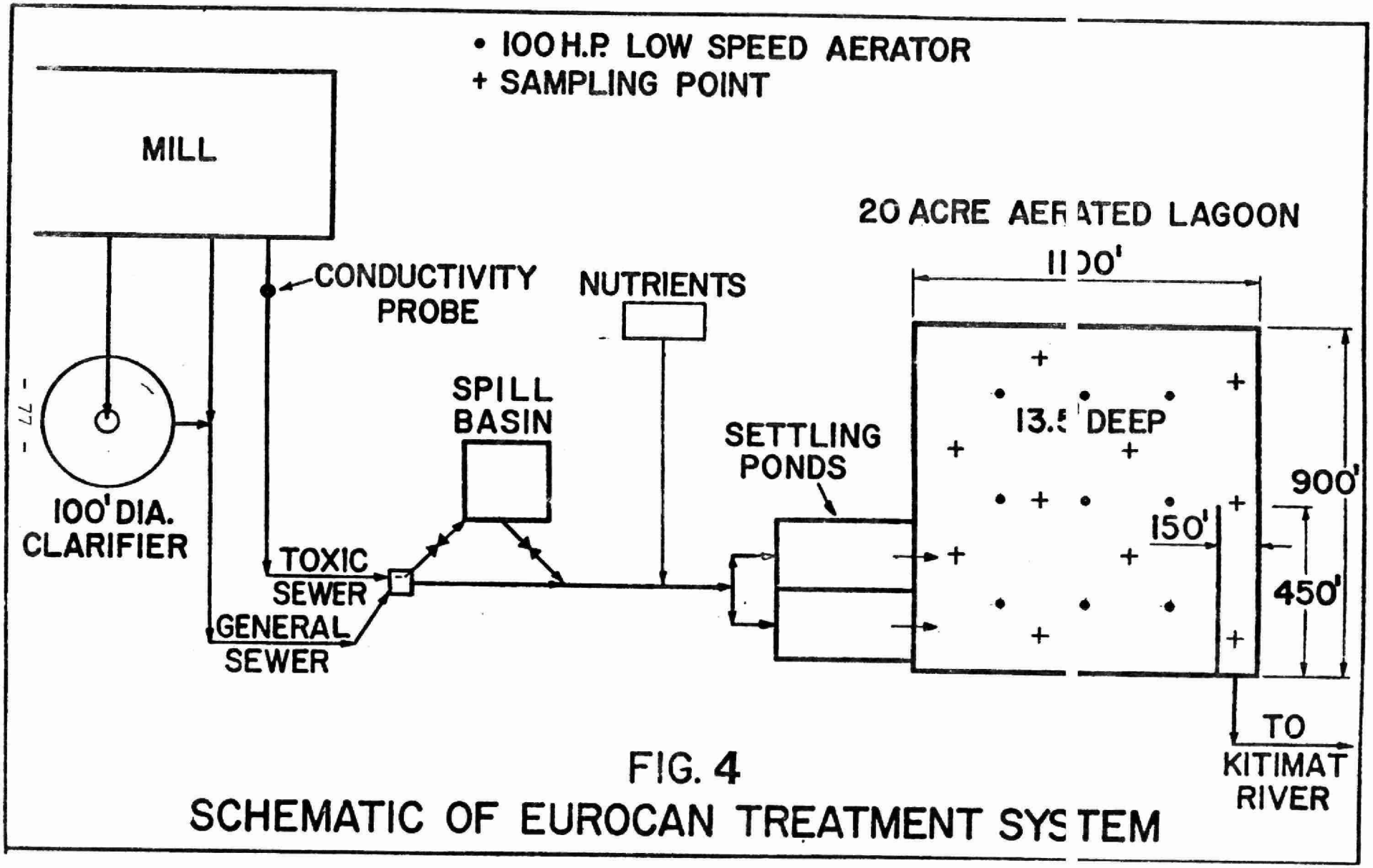


FIG. 4

SCHEMATIC OF EUROCAN TREATMENT SYSTEM

FIG. 5

TYPICAL WINTER OPERATING PERFORMANCE

LOCATION	TEMPERATURE °C			BOD_5 REMOVAL EFFICIENCY
	INFLUENT	EFFLUENT	AMBIENT	
NWP&P	27	13	-10	45%
ALPULP	27	17	0	70%
EUROCAN	25	16	-5	70%

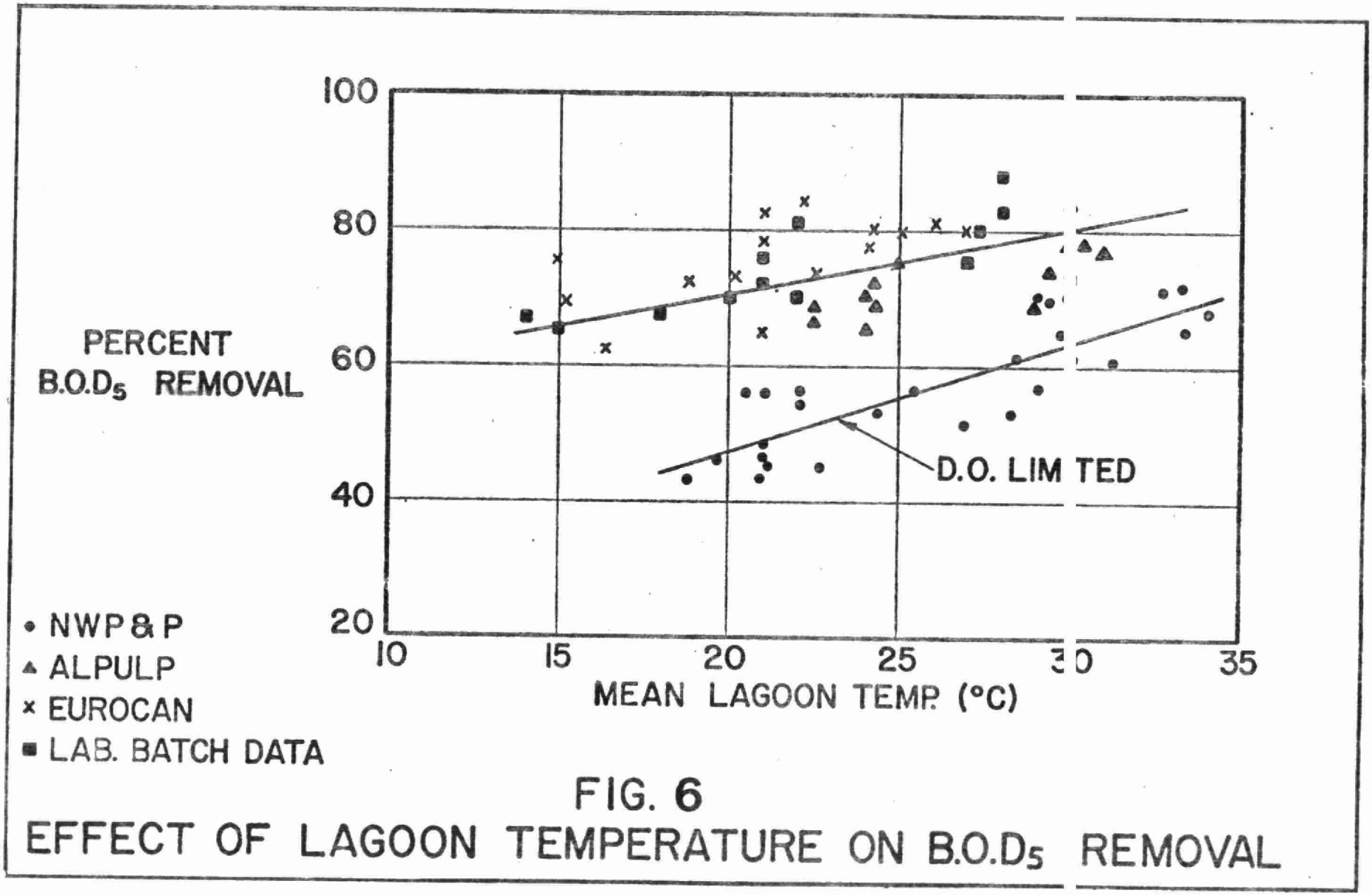


FIG. 6

EFFECT OF LAGOON TEMPERATURE ON B.O.D5 REMOVAL

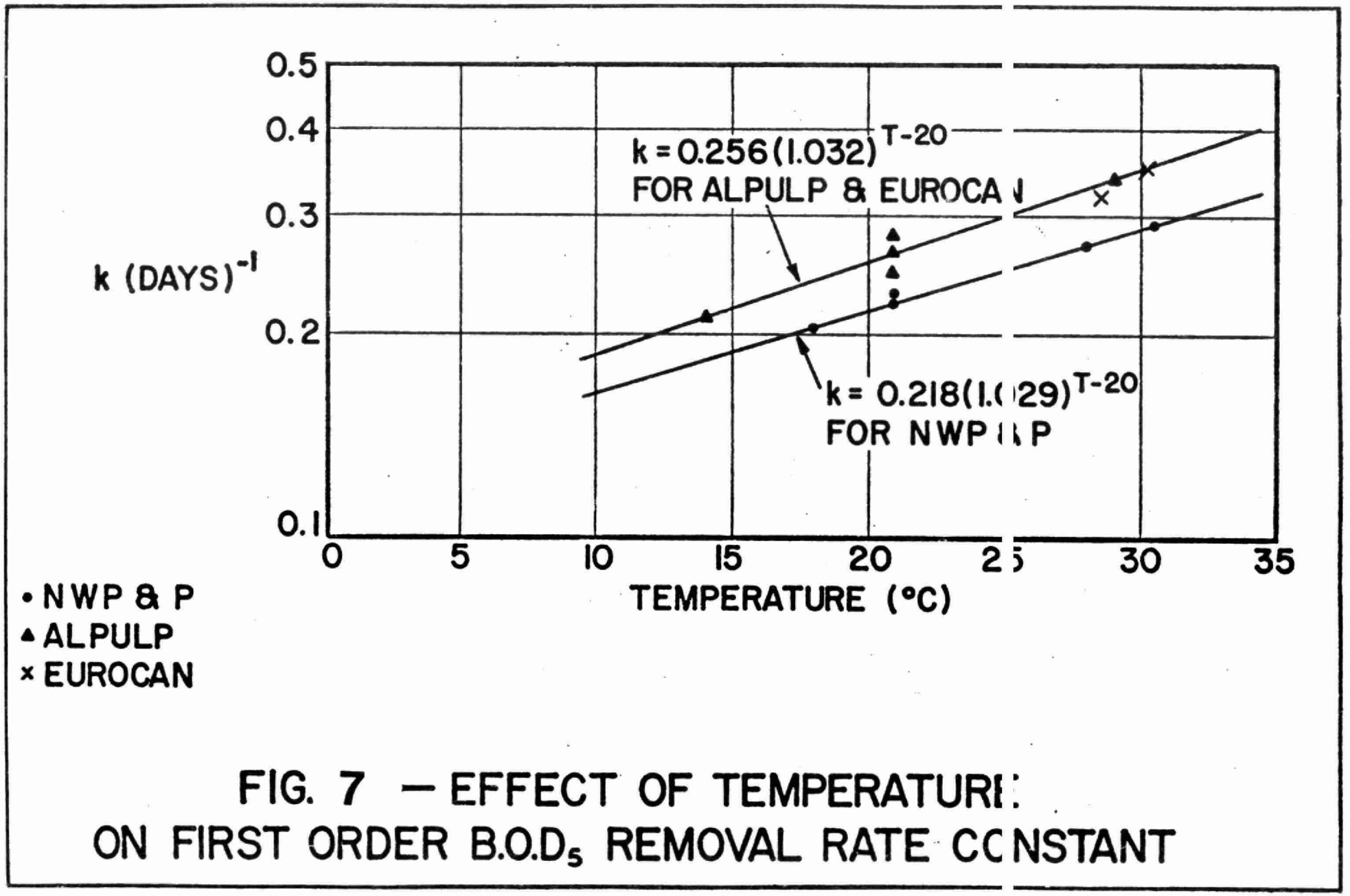
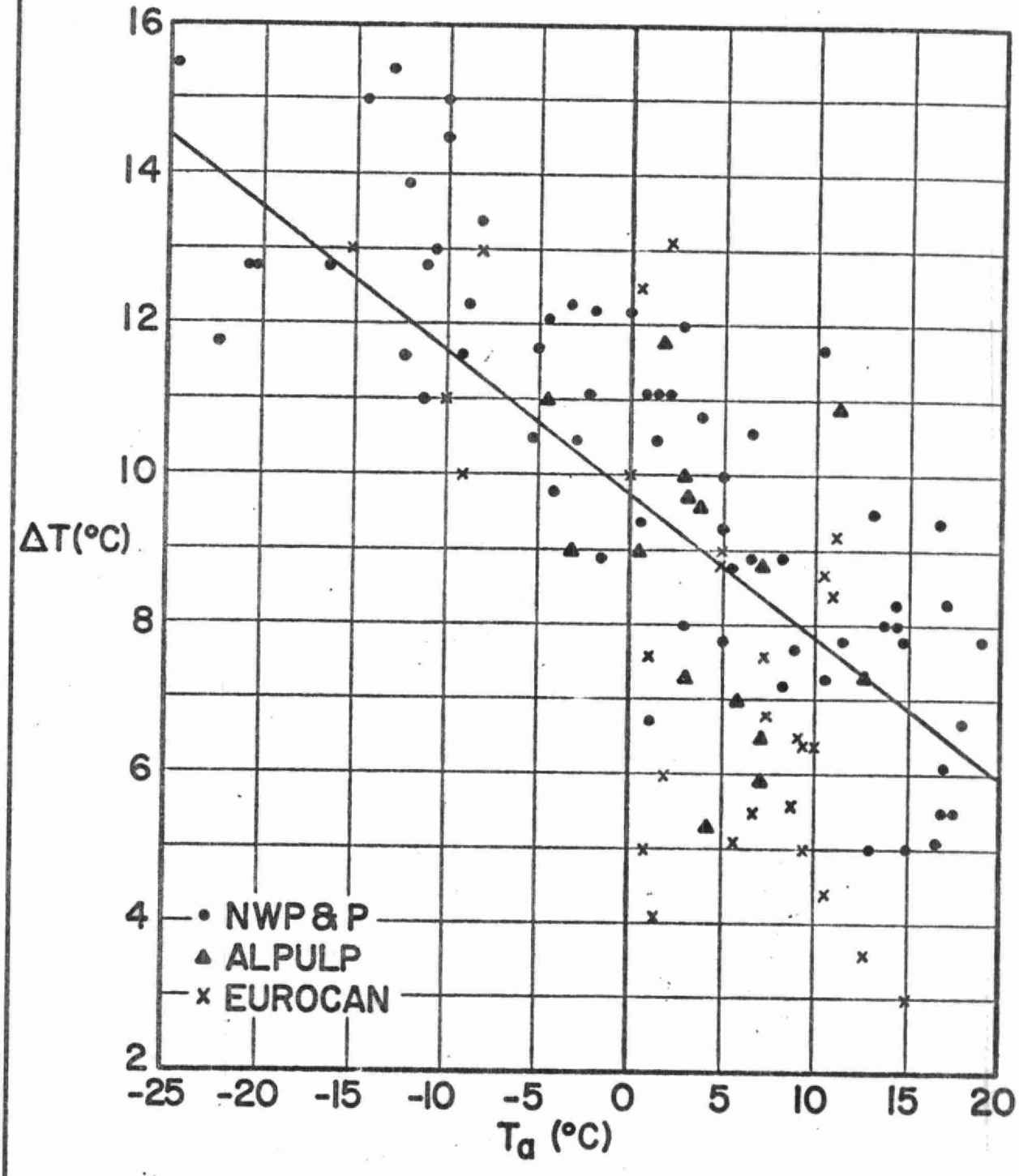
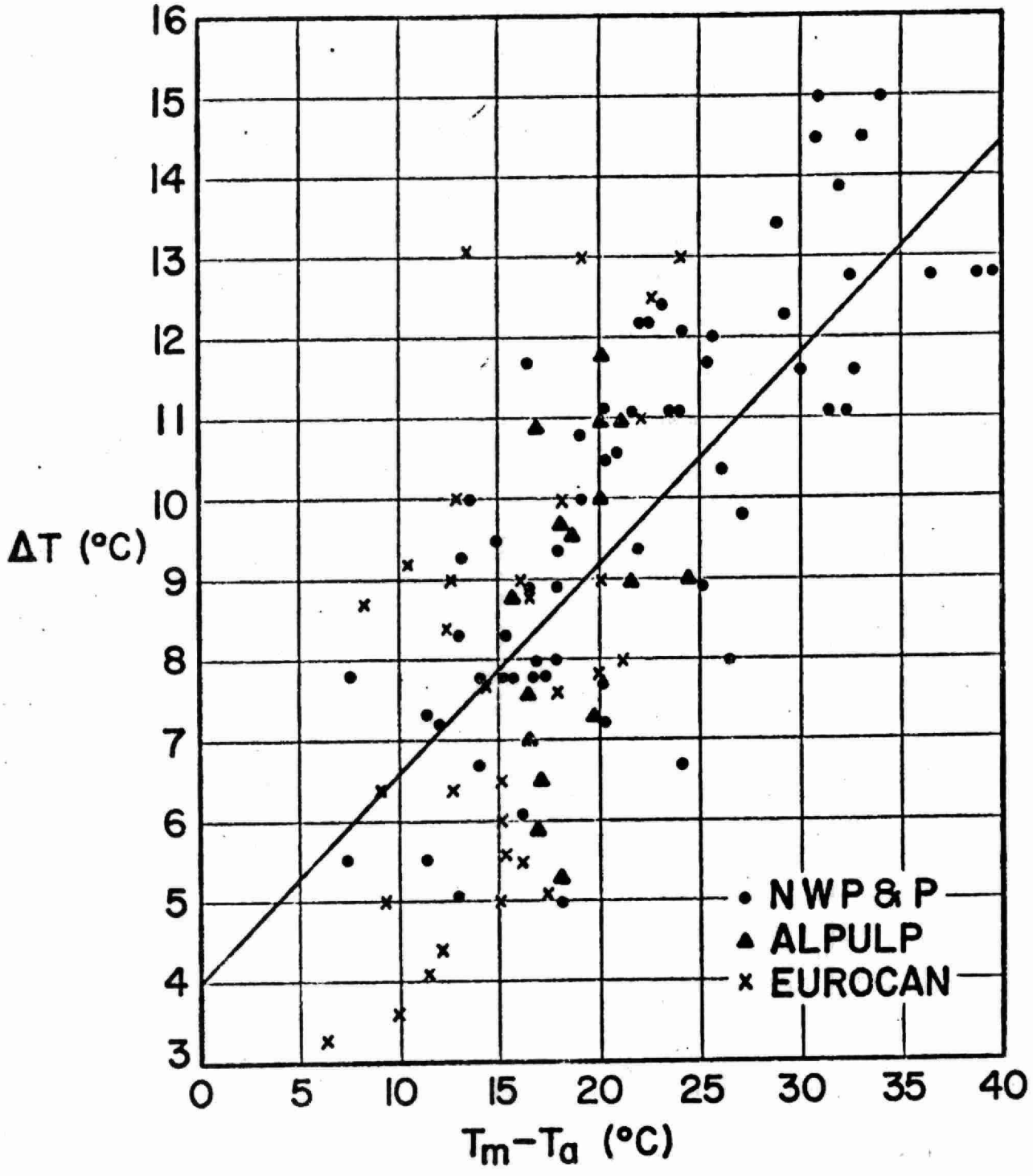


FIG. 7 — EFFECT OF TEMPERATURE ON FIRST ORDER B.O.D$_5$ REMOVAL RATE CONSTANT



SLOPE = -0.190 CORRELATION COEFFICIENT = 0.711

FIG. 8 — TEMP. DECREASE THRU LAGOONS Vs AMBIENT TEMP.



SLOPE = 0.26 CORRELATION COEFFICIENT = 0.738

FIG. 9 – TEMP. LOSS V's MEAN LAGOON TEMP. – AMBIENT TEMP.

FIG. 10

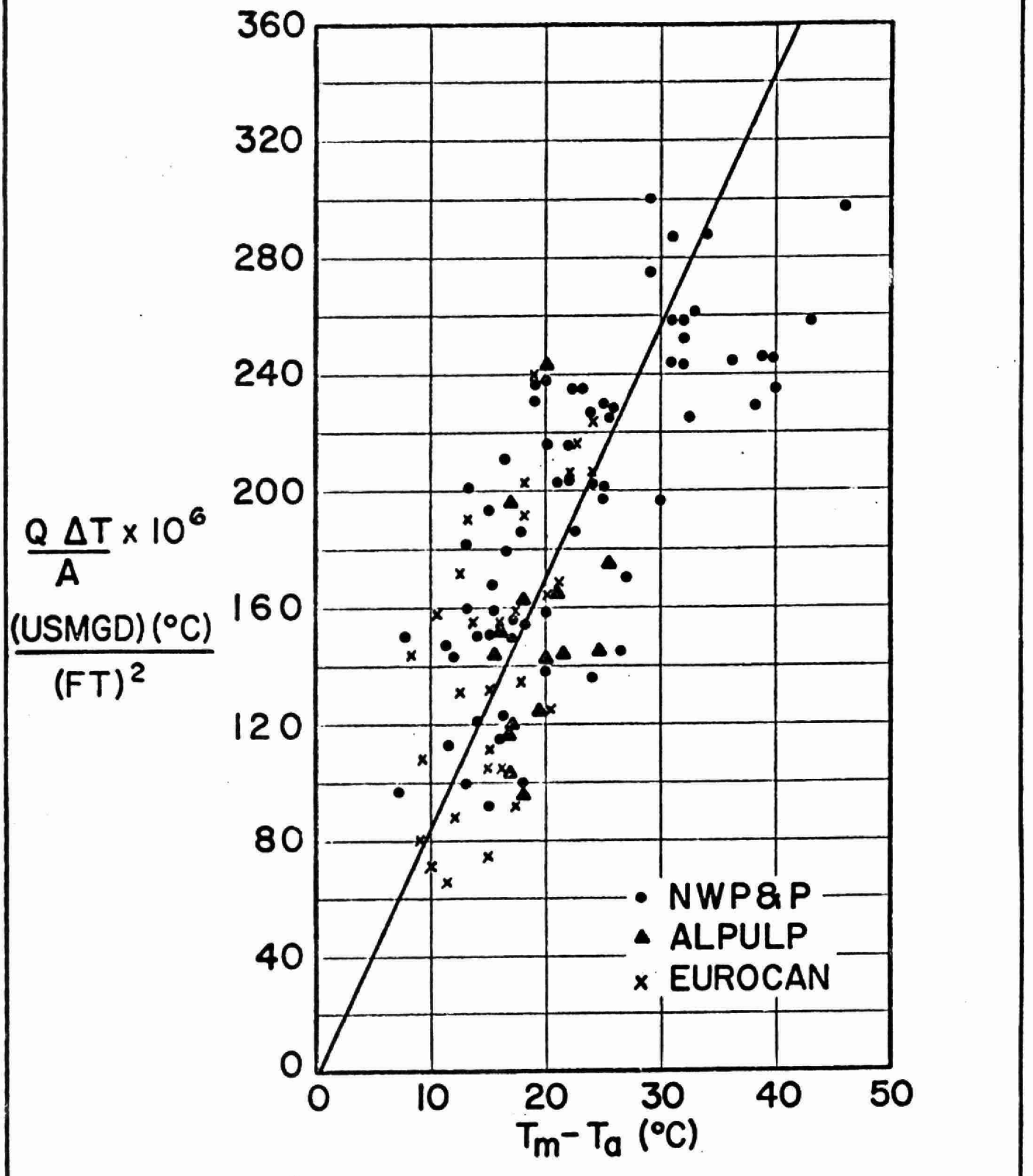
LAGOON HEAT LOSS

a) **PLUG LIKE FLOW** $(T_i - T_e)Q = fA(T_m - T_a)$

b) **COMPLETELY MIXED** $T_e = \frac{fAT_a + QT_i}{fA + Q}$

WHERE:

T_i = INFLUENT TEMPERATURE
T_e = EFFLUENT TEMPERATURE
T_m = MEAN LAGOON TEMPERATURE
T_a = AMBIENT AIR TEMPERATURE
A = LAGOON SURFACE AREA IN SQUARE FEET
Q = WASTE FLOW RATE IN MILLION GALLONS (U.S.) PER DAY
f = PROPORTIONALITY FACTOR OR OVERALL HEAT TRANSFER COEFFICIENT



SLOPE = 8.66×10^{-6} CORRELATION COEFFICIENT = 0.757

FIG. 11 — HEAT LOSS V's MEAN LAGOON TEMP. — AMBIENT TEMP.



D. C. Climenhage



A. Stelzig

BIOLOGICAL PROCESS FOR NITROGEN - BOD REMOVAL AT MAITLAND WORKS, DU PONT OF CANADA LIMITED

BY

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INTRODUCTION

In 1970, Du Pont of Canada began an extensive research and development effort to establish some method of controlling the organic carbon and nitrogen compounds being discharged to the St. Lawrence River from our Nylon Intermediates manufacture.

This study was undertaken to determine the feasibility of a biological process for carbon and nitrogen removal and to provide basic data for process design. Two other processes were studied; both involved evaporation as a first stage, followed by incineration in one case, and high temperature wet oxidation in the other.

SUMMARY

A number of biological treatment schemes were studied and their efficiencies and costs compared with the other processes under consideration.

Repeated evaluation during the course of this study indicated that biological treatment offered the best efficiency for both carbon and nitrogen removal at the lowest treatment cost.

After studying five different biological flow schemes, a two-stage activated sludge system was selected and basic data prepared. The process consists of two basins in series followed by a dissolved air flotation-filter system to clarify the treated effluent and recycle the sludge. The first stage is a fully mixed anaerobic basin for denitrification of the nitrate and nitrite ions to nitrogen gas.

The second stage is an aeration basin designed with three functions. Organic carbon is oxidized by the bacteria to carbon dioxide gas, ammonia is oxidized by nitrifying bacteria to nitrate ion and finally, the extended residence time results in oxidation of most of the excess bacteria produced. Oxygen transfer and mixing is provided in the second basin by mechanical surface aerators.

A pumping station is provided to recycle the mixed liquor of the aerobic second stage back to the anaerobic first stage at a rate up to two times the influent flow. This feature of the process permits removal by denitrification of nitrate ion produced by nitrification of ammonia in the second stage.

WASTE WATER ORIGIN AND COMPOSITION

Du Pont of Canada manufactures the nylon intermediates, adipic acid and hexamethylenediamine, at its Maitland Works located on the St. Lawrence River, 60 miles east of Kingston.

The manufacture of adipic acid involves the air oxidation of cyclohexane followed by nitric acid oxidation and then refining by crystallization. Waste water from these unit operations contains nitrate and nitrite as well as organic carbon. The organics are principally C_1 to C_5 monobasic acids.

Adipic acid is used as feedstock for the manufacture of the other nylon intermediate, hexamethylenediamine. This process includes the ammoniation of adipic acid to nitrile, followed by reduction with hydrogen to diamine and refining by

distillation. Waste water from this process contains ammonia, organic nitrogen compounds and some additional organic carbon.

When we began our experiments the combined process waste water had the following approximate composition. Our early experiments were carried out using this waste.

Nylon Intermediates Waste Water

Total Organic Carbon	3000 Mg/l
BOD	6000 Mg/l
NO_3^- as 'N'	800 Mg/l
NO_2^- as 'N'	90 Mg/l
NH_4^+ as 'N'	230 Mg/l
Organic Nitrogen as 'N'	240 Mg/l.

During the development program, process improvements were discovered that reduced nitrogen loss to the waste water by approximately 50% and our final experiments were completed on the lower strength waste.

BIOLOGICAL DENITRIFICATION

Denitrification[13][5] is a biological process in which bacteria reduce nitrate ion to nitrite and ultimately to nitrogen gas, and this is given off to the atmosphere.

In order for denitrification to take place, two main conditions must be satisfied. First, denitrifying bacteria must have an electron donor and, for practical purposes, this means a source of biodegradable organic carbon. The second requirement is that bacteria must have an anaerobic environment[10] for denitrification to proceed. There has been considerable debate on the role of oxygen in inhibiting denitrification, with many conflicting results[12], but in general, denitrification requires low dissolved oxygen concentrations, below 0.5 mg/l.

The process of biological denitrification has been known for over forty years because of the problem of rising (i.e. non-settling) activated sludge in secondary clarifiers[9][6]: if nitrate is present in the effluent from activated sludge units, denitrification of nitrate ion to nitrogen gas takes place in anaerobic zones in the bottom of the clarifier. The nitrogen gas liberated attaches itself to the sludge floc and causes it to rise to the surface.

DENITRIFICATION EXPERIMENTS

During the first phase of our work two alternate denitrification techniques were studied to remove the nitrate and nitrite ion from the waste using the organic carbon present for denitrification. A stirred reactor[4] [7] process and a column[11] system reported in previous literature were studied as shown in Figures 1 and 2. These experiments were presented in detail in a previous paper[1], and will only be briefly reviewed here.

The column denitrification was soon abandoned because of adverse reaction to feed variation. The plug flow condition of the column resulted in frequent and severe loss in efficiency whenever feed strength increased, while the stirred reactor system was affected very little by the same feed variation.

CONCLUSIONS OF STIRRED REACTOR DENITRIFICATION

(1) The continuous stirred reactor system performed very well with nitrate-nitrite removal efficiencies of 95 to 100% at feed concentrations from 300 to 800 mg/l of NO_3 - NO_2 nitrogen.

(2) The concentrated waste was toxic to the bacteria but could be fed without toxicity problems if diluted 2:1 with water.

(3) We learned that the acidic waste, pH 2.0 to 4.0, could be fed directly to the denitrification reactor without neutralization provided the nitrate loading fed to the bacteria was kept below their denitrifying capacity of .4 gm N/gm VSS/day @ 20°C. (VSS - volatile suspended solids)

(4) The growth rate or cell yield of denitrifying bacteria was low compared to aerobic systems. The value for our waste was 0.13 lb. VSS/lb. BOD removed.

(5) Heavy metal toxicity (Cu^{++}, Co^{++}, V^{+5}) was studied and Cupric ($Cu^{\#}$) ion was found to be the most toxic; shock loadings of 2 - 4 mg/l could be tolerated for a period of one day to one week and a concentration of .5 mg/l indefinitely.

These are similar to results reported for aerobic activated sludge.

(6) A one gallon per minute pilot plant was operated for a period of six months and pointed out a number of

FIGURE 1

COLUMN DENITRIFICATION

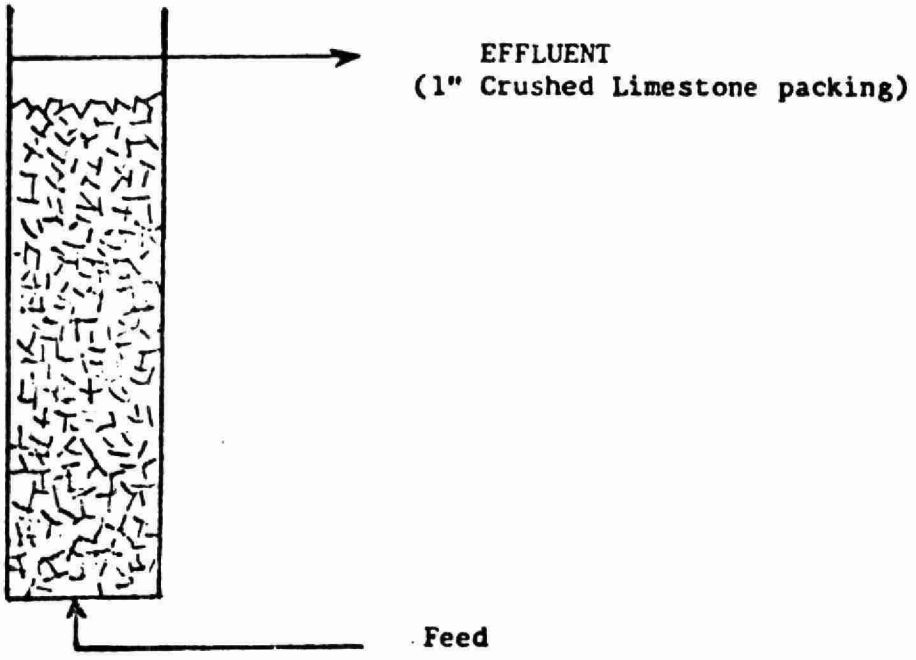
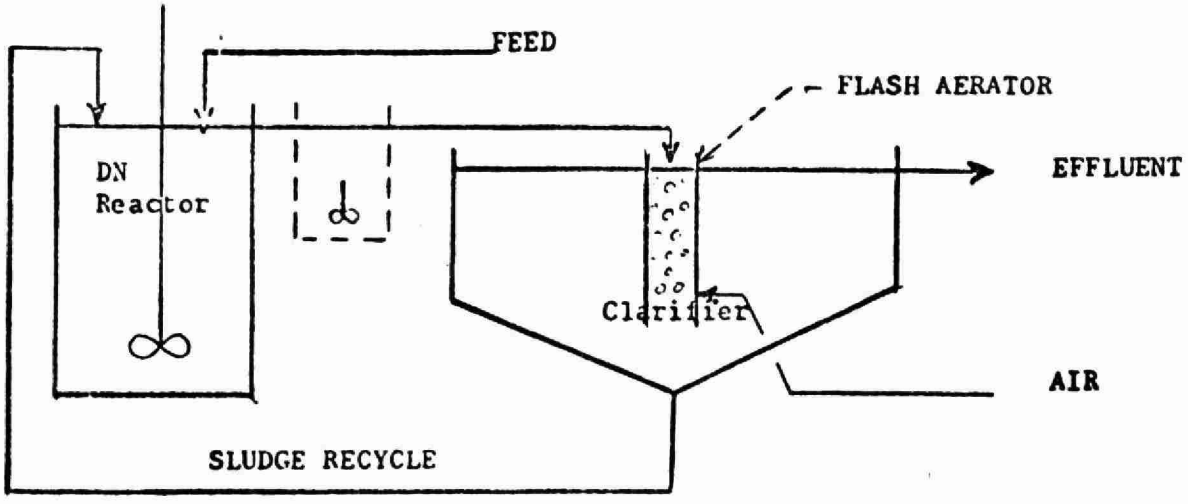


FIGURE 2



operating problems that must be designed for. The clarifier was upset by small nitrate breakthroughs of 10 to 30 mg/l that caused rising sludge. This problem could be minimized by designing into the clarifier system, a peripheral baffle to return floating sludge, surface skimming, positive sludge pick-up and a high sludge recycle rate. The problem cannot be eliminated, however, and may be more severe on scale-up. In the final design the clarifier was replaced by a dissolved air flotation unit to avoid these problems.

Another point learned from our pilot plant was on feed variability. The denitrification reactor must be sized to handle the maximum nitrate-nitrite overload expected or allowance must be made for equalization. If the nitrate-nitrite concentration in the feed exceeds the 0.4 lb. N/lb. VSS/day rate at 20°C, the reactor pH will begin to drop and denitrification will stop if pH goes below 6.0. This is one problem introduced by feeding unneutralized waste.

TWO-STAGE ACTIVATED SLUDGE PROCESS

The next problem we faced was how to incorporate denitrification into an overall process design to achieve maximum BOD and nitrogen removal at the minimum investment and operating cost.

The first process considered was the stirred reactor denitrification system as previously described, followed by an aerated lagoon to remove the remaining BOD. The main disadvantage of this process is that it would not treat the ammonia and organic nitrogen, and the lagoon would be very large (30 days residence time) because of the high BOD concentration.

A number of alternate flow sheets were tried, and the final process selected is shown in Figure 3.

The process consists of two basins in series followed by a dissolved air flotation filter system to clarify the treated effluent and recycle the sludge. The first stage is a fully mixed anaerobic basin for denitrification of the nitrate and nitrite ions to nitrogen gas.

The second stage is an aeration basin designed with three functions. Organic carbon is oxidized by the bacteria to carbon dioxide gas, ammonia is oxidized by nitrifying bacteria to nitrate ion and finally, the extended residence time results in oxidation of most of the excess bacteria produced. Oxygen transfer and mixing is provided in the second basin by mechanical surface aerators.

A pumping station is provided to recycle the mixed liquor of the second aerobic stage back to the anaerobic first stage at a rate up to two times the influent flow. This feature of the process permits removal by denitrification of nitrate ion produced by nitrification of ammonia in the second stage.

The flotation filter system was selected in place of a conventional clarifier because of the floating sludge problems encountered in our pilot plant operation.

DISCUSSION OF RESULTS

The final design was tested on a bench scale system using a clarifier in place of the flotation filter system.

The results are shown in Tables 1 and 2. The data in Tables 1 and 2 have not been adjusted for the evaporation rate of 500 to 700 mls per day out of the feed rate of 2.7 litres per day. When this is taken into account, it is apparent that nitrogen and carbon removal efficiencies are in excess of 85% and 90% respectively.

Figure 3

TWO STAGE PROCESS

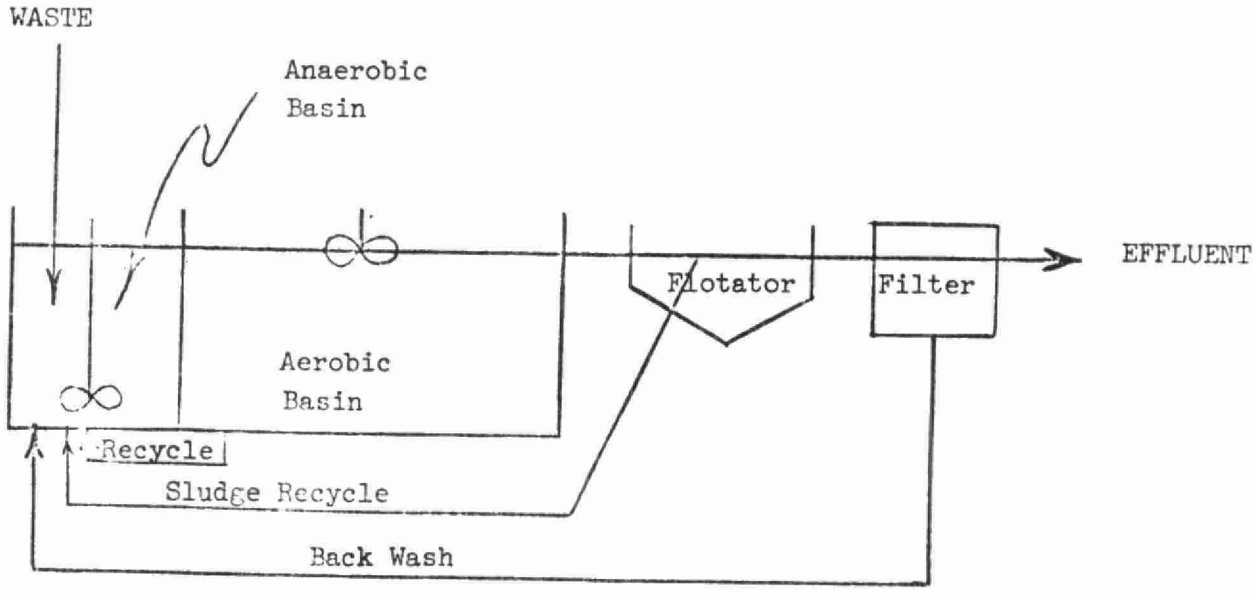


TABLE 1

TWO STAGE ACTIVATED SLUDGE

	FEED Mg/L				1ST STAGE ANAEROBIC Mg/L				2ND STAGE AEROBIC Mg/L				CLARIFIER EFFLUENT Mg/L			
Date	NO_3	NO_2	Red. N	TOC	NO_3 +NO_2	Red. N	TOC	SS / VSS	NO_3 +NO_2	Red. N	TOC	VSS	NO_3 +NO_2	Red. N	TOC	VSS
Jan.72																
18	104	25	200	1114	0		370	692 / 544	18		164	664 / 548				
19					0	66	410		18	38	28					
20					0	55	430		5	34	45		4	32	60	
21					0		490	670 / 515	25		60	720 / 600				
24	130	30	150	1193	0	53	410				80					
25					0	60	490	940 / 800	25	27	80	655 / 565	18	12	60	135 / 135
26					3	52	430		18	19	95					
27					0	55	410		36	9	55		39	7	80	
28					0	56	380		50	0	70					
31	120	49	111	1054	0	44	360		30	7	60					
Feb.72																
1	118	17	135	911	0	55	340	1105 / 915	44	0	60	600 / 495	38	0	60	30 / 26
2					0	50	340	1290 / 1005	27	15	65	1310 / 990				
3	120	15	140	1070	0	50	340		51	0	50		47	0	60	
7	139	16	135	1031	0	67	340		56	2	65					
8							380	1175 / 965			75	1320 / 1055			75	80 / 80
9					0	96	450		68	0	60					
10					0	92	410		62	6	60		70	0	80	
14	119	12	153	1043	0	77	370		60	0	50					
15					0	88	340	1860 / 1475	58	0	60	1190 / 965	52	0	50	62 / 42
16					0	92	390		56	0	65					
17					0	100		1950 / 1550	55	0		2000 / 1600	47	4		
18					0	79			57	0						
21	114	13	203	926	0	59	430		43	13	85					
22					0	98	350	2520 / 2020	33	17	35	2740 / 2200	29	16	40	90 / 77
23					0	66	240		35	13	35					
24					0	75	320	2680 / 2210	40	12	45	2660 / 2220	34	11	50	45 / 45
25					0	69			43	13						
Avg.	122	14.6	153	996		75.8	360		49	5.6			45.2	4.4	59.2	

% N removed = 86.7%

TABLE 2

TWO STAGE ACTIVATED SLUDGE

STAGE DATA

Date	FEED Mg/L.				1ST STAGE ANAEROBIC Mg/L				2ND STAGE AEROBIC Mg/L				CLARIFIER EFFLUENT Mg/L			
	NO_3	NO_2	Red. 'N'	TOC	NO_3 +NO_2	Red. 'N'	TOC	SS VSS	NO_3 +NO_2	Red. 'N'	TOC	VSS	NO_3 +NO_2	Red. 'N'	TOC	SS VSS
Feb.																
28	104	13	218	-	3	54	-		36	22	-					
29	97	74	254	900	0	57	160		37	17	55		35	20	55	
Mar.																
1					0	64	80	3690/2920	31	19	40	2270/1950				30/30
2					0	-	90		31	-	50		28	-	40	
3					0	-	-		64	-	-					
6	107	70	323	1053	0		400	2700/2290	37		35	1870/1630				84/24
7					0	172	510		43	39	72		40	14		
9					0	160	460		52	23	50		42	23	55	
10					0	130	430		59	15	51					
13	97	80	333	1054	0	142	460		60	18	65					
14					0	144	510	2520/2135	57	21	90	2025/1790				26/21
15					0	154	560		79	21	28					
16					0	150	480		52	34	52					
17					0	138			68	18						
21	129	72	279	1075	0	162	570		66	37	44					
22					0	144	570	2920/2470	85	15	40	1940/1640				46/34
23					0	160	600		64	34	32					
27	120	65	315	1133	0	148	580	2650/2100	78	22	32	2030/1690				
28					0	130	570		60	34	32					
29					0	134	600		72	38	30					
30					0	148	620		68	40	40					
Apr.																
3	129	61	280	1193	0		470	2600/2000	58		40	2000/1800				40/40
4					0	110	480		57	27	36					
5					0	136	580		79	8	32					
6					0	-	580		59	-	28					
7					0		570		42		32					
	112	62	286	1068	0	132	475		57	25	44	Average				
									46	20	35	Corrected for Evaporation				

% Nitrogen Removed 85.7%

The data in Table 1 represent a run at nitrogen concentrations close to the expected levels on the full-scale plant. The average nitrogen removal, including correction for evaporation, was 86.7%. The recycle rate was maintained at 1:1 during this run.

The anaerobic first stage gave complete removal of nitrate and nitrite nitrogen fed to it. Of the remaining reduced nitrogen compounds, 72% were removed.

The high removal of reduced nitrogen is even more pronounced in the data of Table 2. During this test run, reduced nitrogen in feed was almost doubled, the average feed concentration of reduced 'N' for the run being 286 mg/l. Once again, the first anaerobic stage gave complete removal of all nitrate and nitrite. The recycle ratio was maintained at 1:1 with the feed. The total nitrogen in the aerobic stage was 66 mg/l. This represents a 73% removal of the reduced nitrogen and an overall removal of 86.7%.

DISSOLVED AIR FLOTATION - FILTER SYSTEM

One of our major concerns in the design of the two-stage activated sludge system was the operation of the clarifier considered initially. It was apparent that during periods of high nitrate in effluent from the second stage, floating sludge in the clarifier could be a serious problem. A number of design features were included to combat this, as discussed in the stirred reactor denitrification section, but these would not be enough to prevent some sludge loss during an upset.

In addition to the floating sludge problem, the laboratory two-stage unit periodically experienced sludge bulking problems in which the sludge at 2000 mg/l SS would only settle to 80% of its volume with settling times over 1 hour. This situation could be corrected by addition of polyelectrolytes, but this could result in an annual cost of from thirty to fifty thousand dollars.

Eimco Canada Ltd. proposed that a dissolved air flotation unit would eliminate these problems. Floating sludge due to denitrification would have no ill effect on a flotator and even a bulking sludge can be thickened by flotation, because of the greater forces applied to the floc than those possible by gravity settling. Dissolved air flotation tests were carried out as outlined by Eckenfelder[2]. In these tests, sludge is mixed in a cylinder with a fraction of clarified effluent (recycle) that has been saturated with air under pressure. Various percentage recycle and air pressures were

tried and these results are shown in Table 3. These tests were conducted at a time when sludge from the test unit was practically non-settleable without polyelectrolyte addition.

The results indicated dissolved air flotation would work and an effluent solids of 40-80 was possible without polyelectrolyte addition and 10 to 20 ppm solids with 5 ppm of Rohm and Haas C-3. A recycle rate of 50% is more than adequate.

In subsequent talks with Eimco it was decided that a gravity type dual-media filter could polish the flotator effluent and eliminate the necessary of electrolyte addition.

It was decided then to remove and recycle the bulk of the sludge by dissolved air flotation, reducing the effluent solids to 50-110 mg/l and the filter would then be designed to reduce the effluent solids to 10-30 mg/l.

This concept of flotator-filter was adapted to replace the clarifier on the basis that it would eliminate polymer cost and eliminate the problems due to using sludge in a clarifier.

PERFORMANCE AND COST

Expected cost, efficiency and final waste composition to be treated are summarized below:

Treatment Capacity

2.5 millions of gallons/day
50,000 lb./day BOD
8,000 lb./day Nitrogen

Capital Cost

$2,000,000

Operating Cost

$175,000 per year
or 19¢/1000 gallons.

TABLE 3

DISSOLVED AIR FLOTATION TESTS

Test Conditions	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Sludge Conc. (Mg/L)	2000	2000	2000	2000	2000	2000	2000	4000	1( )0	200	200	4000
% Recycle	%	50%	50%	100%	100%	100%	100%	100%	1( )%	100%	100%	100%
Air Pressure PSIG	65	65	40	50	65	65	65	65	65	65	65	65
Floc (R + H) C-3	No	No	No	Yes	Yes	Yes	No	Yes	]es	Yes	No	No
Floc Cond. (ppm)	0	0	0	5	5	2	0	5	5	5	0	0
1 min. Sludge Vol.	2.5cm	2.8cm	2.8cm	3.0cm	3.0cm	3.4cm	3.8cm	7.5cm	1 3cm	0.3cm	0.3 cm	14cm
5 min. Sludge Vol.	2.2cm	2.2cm	2.2cm	2.2cm	2.2cm	2.5cm	2.5cm	4.8cm	1 3cm	0.3cm	0.3 cm	6.7cm
20 min. Sludge Vol.	1.9cm	1.9cm	1.9cm	1.9cm	1.9cm	2.2cm	2.2cm	3.8cm	1 3cm	0.3cm	0.3 cm	3.9cm
Sampled for Solids	"	"	"	"	"	"	"	"	"	"	"	"
Solids (Mg/L)	158	44	64	20	10	26	80	44	4	24	80	60
Special Remarks	Cloudy	Clear	Fair	Clear	Clear	Clear	Cloudy	Clear	C ear	Clear	Cloudy	Cloudy
Filtering	Slow	Fast	Good	Fast	Fast	Fast	Slow	Fast	F t	Fast	Slow	Slow

FILTER PAPER USED: Whatman, Glass Fibre Paper
4.25 on GF/A

Waste Composition To Be Treated (after 2:1 Dilution)

BOD	2000 mg/l
TOC	1000 mg/l
NO_3^--N	100 mg/l
NO_2^--N	80 mg/l
NO_4^+-N	110 mg/l
Organic-N	30 mg/l

Efficiency (Summer)

95 - 98%	BOD
85 - 90%	TOC
80 - 85%	Total Nitrogen.

The nitrogen and BOD efficiencies are expected to decrease during winter operation. Design calculations show this to be a minor decline (less than 10%) but since the system was not pilot plant tested, the nitrogen removal efficiency during winter will not be known for certain until our first winter's operation.

The capital cost of two million dollars includes the waste water collection and segregation system, the complete process and the effluent piping.

Operating cost does not include any depreciation but does include power, phosphate, occasional neutralizing chemical addition, an operator and maintenance.

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DEVELOPMENT AND IMPLEMENTATION OF A TWO-STAGE BIOLOGICAL PROCESS FOR HIGH STRENGTH WASTES

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INTRODUCTION

National Starch and Chemical Company (Canada) Ltd. brought a new starch plant into production in Collingwood, Ontario in 1969. It is a wet milling plant for separating corn into its components and produces low-and high-protein byproducts, corn germ and starch.

As the name implies, National is primarily interested in the starch and is unique in that almost all the starch produced is chemically modified into specialty starches.

The separation facility itself produces no effluent and there would be no effluent problem if it were not for the heavy emphasis on specialties. When starch molecules are changed by chemical reaction, some starch becomes solublized and some inorganic salts are formed. These are washed out in a washing system and the effluent from that system is fed to the treatment plant.

Plant operation is such that one product is manufactured at a time for periods ranging from one day to several weeks in succession. In all, there are six or seven principal product types manufactured.

Concurrent with the design of the manufacturing facility, National installed an effluent treatment facility consisting of a single-stage biological filtration unit with plastic media. The objective of the waste treatment plant was to meet the Town of Collingwood's Waste Discharge ByLaw for acceptance into the public sewers.

The trickling filter plant was put into operation in June of 1969. Shortly thereafter, it became apparent that the Town's effluent objectives were not being met and increasing pressure was applied on National to remedy the situation. Pollutech was engaged by National in November 1969 to determine the causes of malfunction and to recommend a practical solution for National in order that they could consistently meet the discharge ByLaw limit.

INITIAL EVALUATION

An evaluation program was carried out in late 1969 and early 1970 to assess the quality of the raw waste and to evaluate the performance of the treatment plant. Since several different products are manufactured at the Collingwood plant, the evaluation was carried out over a sufficient period of time to span the wastes from several of the product types.

Table 1 shows waste concentrations during this evaluation period for the product types designated as A, D and F. In addition, the Table shows the total organic carbon of the trickling filter effluent as well as the raw waste material.

TABLE 1 INITIAL EVALUATION OF ORIGINAL PLANT

Product Type	Raw Waste Total Organic Carbon (mg/l)	Treated Effluent Total Organic Carbon (mg/l)
F	1,010	530
A	-	750
	620	-
	800	425
	940	360
	-	350
	-	525
D	1,500	1,750
	3,000	-
	5,200	2,750
	2,960	5,520
	4,120	3,050
	3,600	2,240
	3,000	2,000
	3,100	-
	3,040	2,000
	2,660	2,600
	3,640	2,680
	4,320	-
	2,760	-
	3,600	-
	2,080	-

Table II, below, shows the average strength of waste from each of six product types in terms of soluble five-day BOD and soluble organic carbon.

TABLE II

Product Type	Soluble BOD_5 (mg/l)	Soluble Organic Carbon (mg/l)
A	1000	870
B	1200	1840
C	5900	5500
D	7400	5300
E	8500	5300
F	2100	1000

Following the initial evaluation of the treatment plant during manufacture of some of the product types, a preliminary study was initiated to evaluate the biodegradability of several of these products. The purpose of this study was to determine the extent to which each of these products could be biologically degraded under different treatment conditions in order to see if, in fact, the effluent objectives could be met. In all cases, it was determined from batch biodegradability studies, that the wastes could be degraded down to acceptable levels. An expanded program was then undertaken to develop design criteria for a biological treatment system which could produce an acceptable effluent from the wastes at National's Collingwood plant.

DEVELOPMENT OF PROCESS DESIGN

Figures 1, II and III show the result of batch biodegradability evaluations under various conditions on three of the product types. In each case, it is seen that an effluent quality can be obtained which can meet the discharge limits of 300 ppm BOD; however Figure IV shows that product type "C" does not degrade, even after a period of some 72 hours. Further examination showed that this product had a chloride concentration well in excess of 10,000 ppm which inhibited biological activity. A dilution of this product to lower the chloride concentration to normal tolerable limits resulted in a degradation of the product as shown in Figure V.

Several experimental programs were then carried out in batch biological reactors, in order to assess the ability of a biological system to degrade various of these product types as manufacture alternated from one product to another. The result of this program indicated that a biological reactor would require the residence time well in excess of 200 hours, in order to ensure that all product types could be handled and an acceptable effluent produced.

In an attempt to explore possibilities of alternative biological processes which could reduce the long residence time, batch studies were carried out to determine if there would be any advantage to a two-stage process. These tests showed that wastes which had been partially degraded in a batch reactor could be acclimatized to a new group of organisms and degraded at a faster rate. Thus it was indicated that a two-stage process could achieve in less than 72 hours, organic carbon levels equivalent to that obtained in a single reactor in more than 200 hours. Figure VI shows this phenomenon.

In order for a two-stage mixed biological process with recycle to be economically realistic, the saving in reactor volume must be more than offset by the cost required for the additional clarifier and sludge handling system. In this case, because waste strengths reached as high as 9,000 mg/l of five-day BOD, yet flow volumes were less than 100,000 gals/day the additional clarifier represents only a small additional cost in relation to the savings in reactor volume. Hence, in other cases where large flows with a weaker waste showed the same phenomenon as Figure VI, such a two-stage would not be economically realistic even if it was technically feasible. Confirmation of the above phenomenon was obtained through the operation of a continuous, two-stage laboratory pilot plant for a period of six weeks. Figure VII shows BOD concentration of the effluents from each stage during this type of operation.

Figure VIII shows the process flow sheet proposed as the requirement for a biological treatment plant capable of meeting the effluent discharge requirements for the wastes produced by National's Collingwood plant. Additional design considerations included provision for successful cold weather operation during the three days' required retention in the treatment system, as well as provision for nutrient control and pH adjustment.

The design criteria for the principal components of the proposed process are shown in Table III, as follows:

DESIGN CRITERIA

TABLE III

1. Flow: 70 USGPM

2. Quality of raw waste:
   15% of time 8,000 ppm BOD
   25% of time 4,000 ppm BOD
   60% of time 1,000 ppm BOD

3. Aeration tanks:

   a) 1st stage
   - nominal retention time - 36 hours
   - capacity - approx. 150,000 US gals.
   - maximum oxygen requirements - 4,300 lbs /0_2/day
   - sludge recycle - 35 - 210 US gpm
   - mixed liquor suspended solids -5000 $\pm$ mg/l

   b) 2nd stage
   - nominal retention time - 36 hours
   - capacity - approx. 150,000 US gals.
   - maximum oxygen requirements - 1,850 lbs/0_2/day
   - sludge recycle - 35 - 210 US gpm
   - mixed liquor suspended solids - approx. 3 - 4,000

4. Clarifiers:

   Both clarifiers are identical.

   - nominal retention time - 3.6 hours
   - capacity - approximately 15,000 US gals.
   - loading rate - 300 US gals./sq/ft/day

5. Aerated sludge holding tank:

   - retention time - variable according to strength of waste
   - capacity - 30,000 US gals.

NOTE: pH in aeration tank will have to be maintained in the range 6 - 8. Both nutrients - Nitrogen and Phosphorus - will be added in ratio BOD:N:P - 100:5:1.

IMPLEMENTATION OF CONSTRUCTION PROGRAM

The approach taken in turning the process design into reality was one which had served NATIONAL well in the past. The principle of this system is that NATIONAL acts as the Project Manager and subs out detailed engineering and preparation of drawings, and hires and co-ordinates subtrades. Hence, this system eliminates both the traditional roles of the consulting engineer as a co-ordinator and project manager and that of general contractor as a co-ordinator of subtrades.

The first step in this procedure involved utilizing a local engineering firm, Ainley & Associates, to make foundation investigations and provide a cost comparison between steel or concrete tanks and lined-earth tanks. On the basis of this cost comparison, it was determined that the aeration basins should be built of compacted fill and lined with a gunnite.

Once the shape of the aeration basins had been determined on a construction cost basis, arrangements were made to tender for the supply of major equipment to meet the performance specifications set out in POLLUTECH's process design. Since deep tanks were used both for construction economy and for minimizing heat loss, the oxygen transfer equipment which met the requirements in all respects was submerged turbine aeration equipment with a sparge ring at the bottom and two sets of mixing impellers. Thus, the aeration equipment, clarifiers, pumps and blowers could be ordered in the early Fall of 1970 with all deliveries scheduled prior to the end of February, 1971. Hence all equipment purchased directly by NATIONAL was on the site before any of the contractors commenced their activities.

During the detailed structural and mechanical design, considerable attention was given to practical aspects of layout, winterization and operating convenience. A two-floor control building was selected, whereby all main process lines pass through the basement in order that all valves could be operated from indoors. The piping system was arranged in such a way that any of the main process components could be out of service, yet the plant could remain operational.

Since this construction implementation system inherently avoids time delays because of communications between owner, consulting engineer, general contractor and contractor, the construction schedule was set up on the basis of an eight-week construction program.

One of the first decisions in construction implementation concerned dewatering. Since the bottom of the aeration basins was below the water table, it was decided that some $1,500 should be spent immediately to construct gravel sumps for dewatering in order to avoid the time delay and the higher cost of well-pointing at a later time. Clarifier erection and electrical installations were done by the contract maintenance personnel, utilized in NATIONAL's manufacturing facility.

Tree-clearing was started during the first week of April and the treatment plant went into operation on June 1st. The budget for the complete installation was $260,000 and the final total project cost was $261,113.37. Hence it can be seen, both from a scheduling point of view and from cost control, that this construction implementation system was ideally suited to this particular project.

OPERATION EVALUATION

After the initial period of treatment plant start-up and operational adjustments, a regular routine was established whereby one of National's plant engineers was responsible for routine operation of the plant on a part-time basis. At the same time, the quality control laboratory expanded their capacity in order to analyse for BOD, COD, Suspended Solids and Nutrients. A log was kept of routine operations, with effluent COD as the key parameter in daily operational control.

Following an initial operating period of almost one year, a detailed operational evaluation was undertaken in the summer of 1972. During this period, one laboratory technician was assigned essentially full-time in order to measure sufficient parameters on a regular basis over an extended period of time to establish performance patterns for the plant. During the two-month period, samples were collected every two or three days and performance evaluated.

During this evaluation period, the influent waste BOD to the two-stage biological process ranged from approximately 500 ppm to 5500 ppm. However, the effluent concentration was less than 300 ppm BOD except for one day and averaged approximately 50 ppm. Figure IX shows a Probability Plot of BOD for both the influent and effluent from the two-stage plant during this period. Similarly, Figure X shows a Probability Plot for the same samples in terms of total organic carbon.

Thus, it can be seen that performance of the full-scale plant lived up to and exceeded the expectations based on the laboratory pilot-scale units used to obtain process design criteria.

NATIONAL'S PHILOSOPHY ON PLANT DESIGN

It is of interest in this paper to comment on this effluent treatment solution at National's Collingwood plant with respect to some very basic Company philosophy.

During the design and construction of the manufacturing facilities at Collingwood, a "custom design" approach was used throughout. This resulted in non-standard techniques in building construction and in several of the manufacturing process operations, particularly the drying equipment. The dryers were custom designed and fabricated locally. However, during the design of the manufacturing facilities, the waste treatment design was regarded as a "tack-on" and hence it was assumed that a package-type facility could be used. Consequently, rather than using a consultant, a facility was purchased on the recommendation of a supplier - in effect, in violation of the principles used to build the manufacturing facility. When this packaged plant failed to produce satisfactory effluent, National reverted to the custom approach.

It is interesting now, in retrospect, to see that the approach eventually used to solve the effluent treatment problem by utilizing the custom design, even though no precedent existed, was really an extension of the philosophy used for the manufacturing facilities.

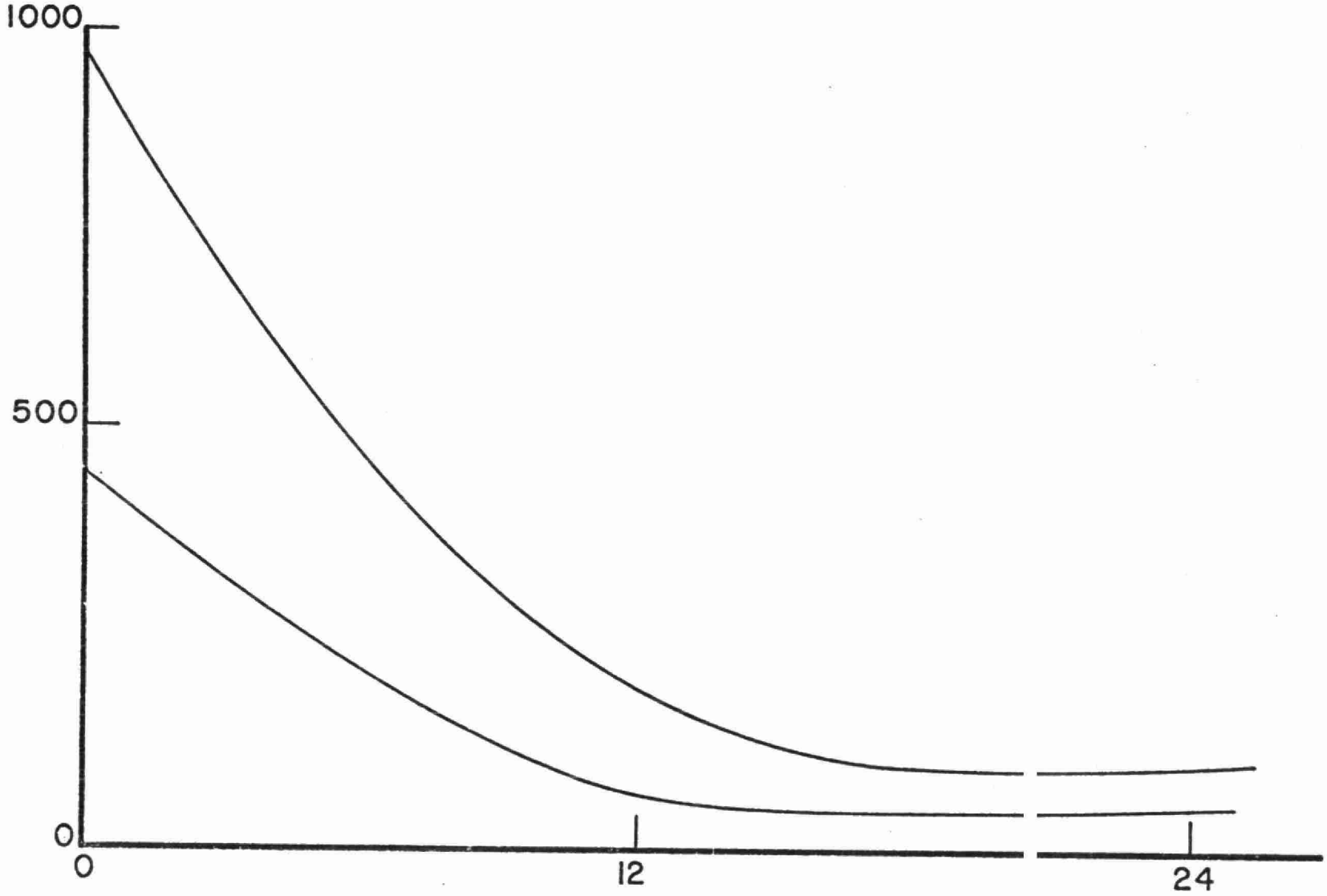


FIGURE I. BIODEGRADABILITY STUDY – FEED "A"

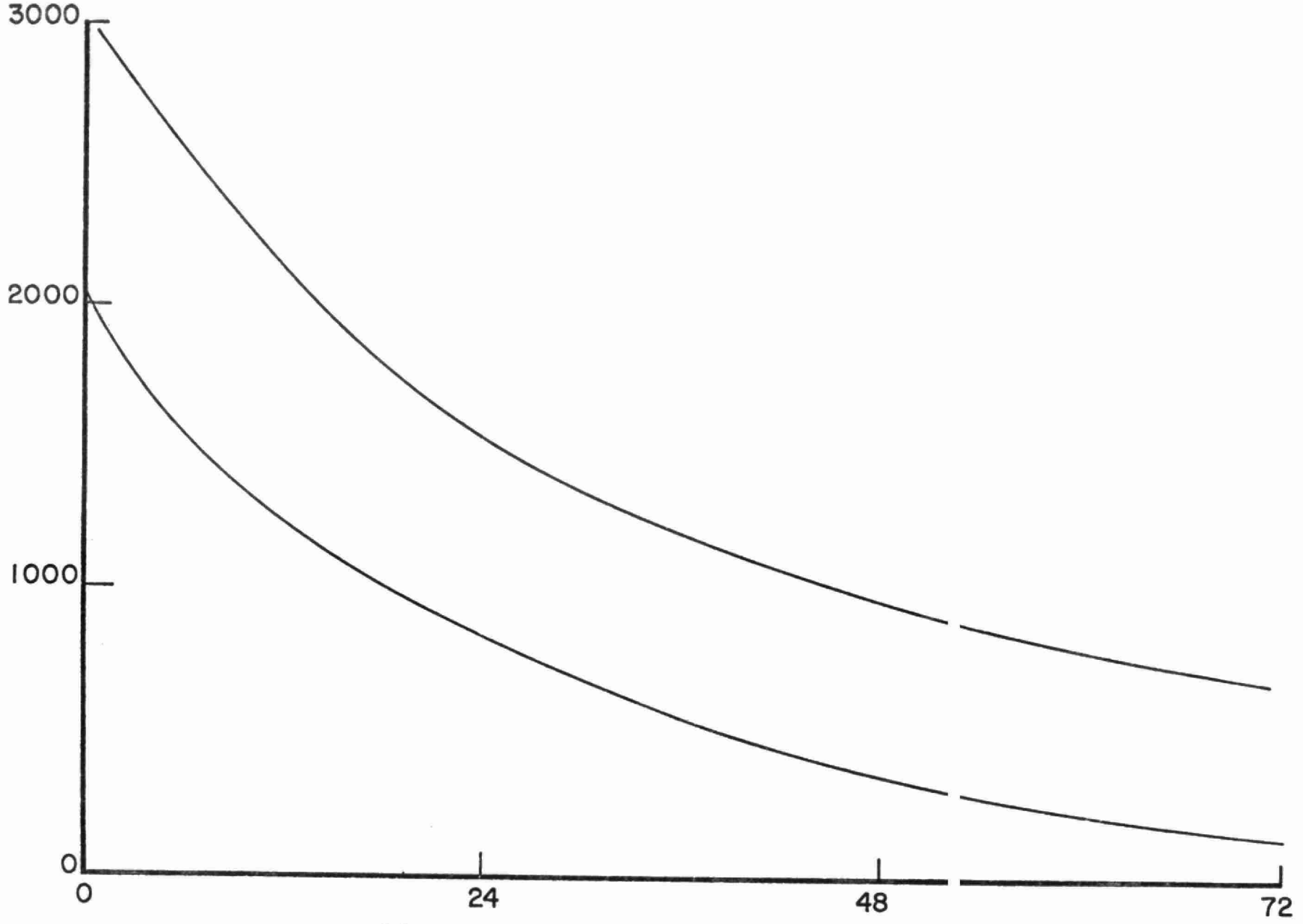


FIGURE II. BIODEGRADABLE STUDY – FEED "D"

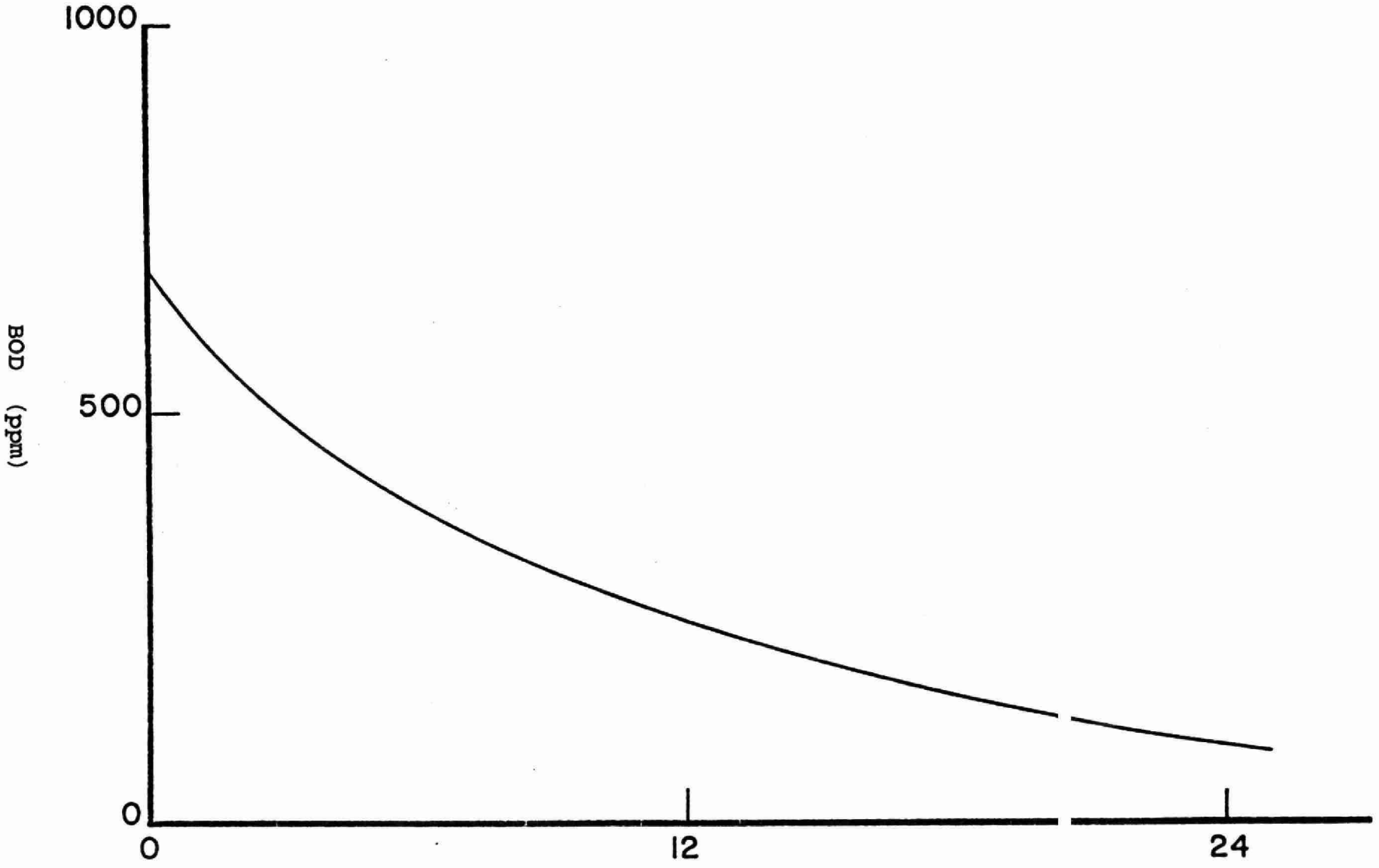


FIGURE III. BIODEGRADABILITY STUDY– FEED "F"

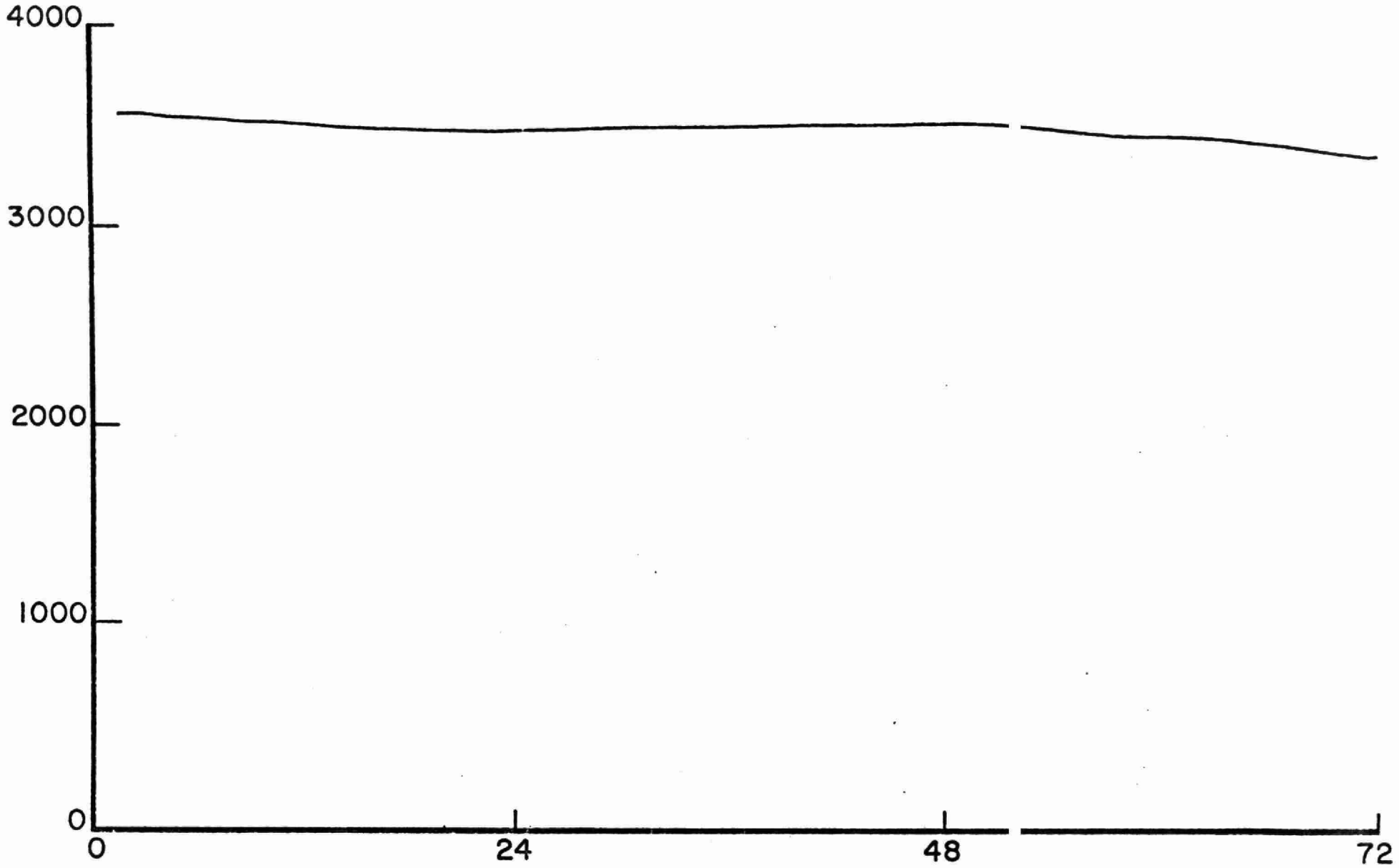


FIGURE IV. BIODEGRADABILITY STUDY – FEED "C"

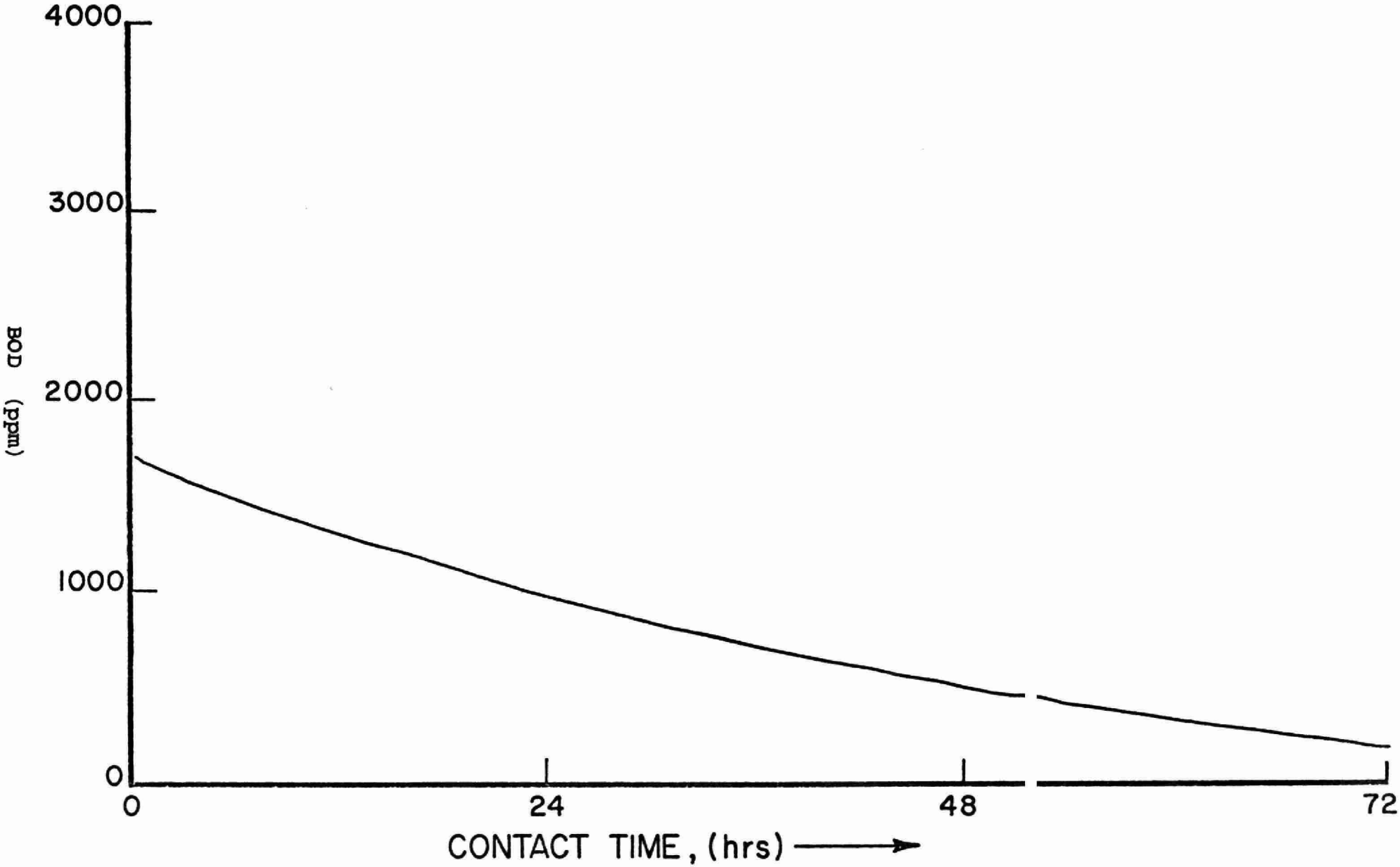


FIGURE V. BIODEGRADABILITY STUDY– FEED "C" – DILUTED BY 50% WITH WATER

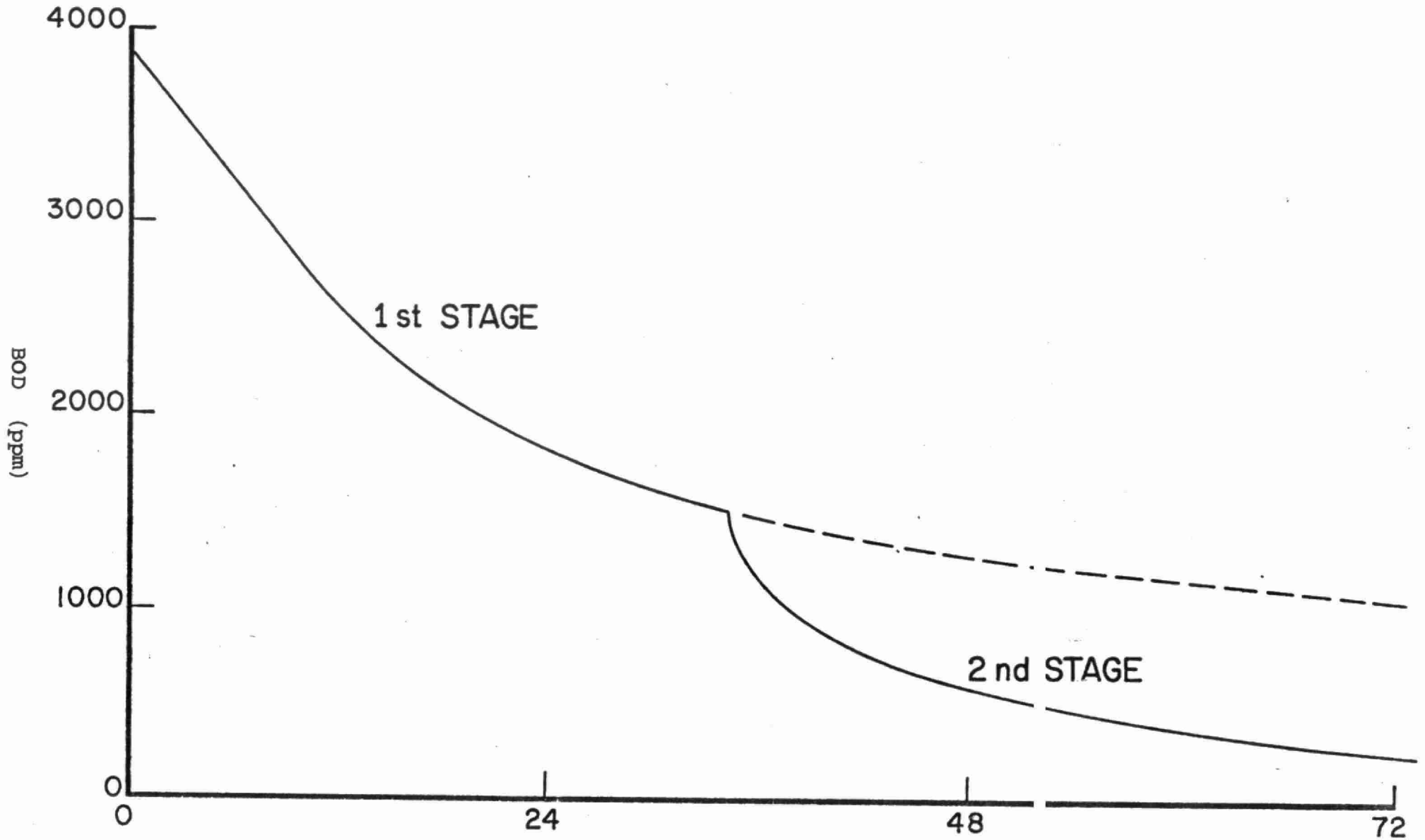
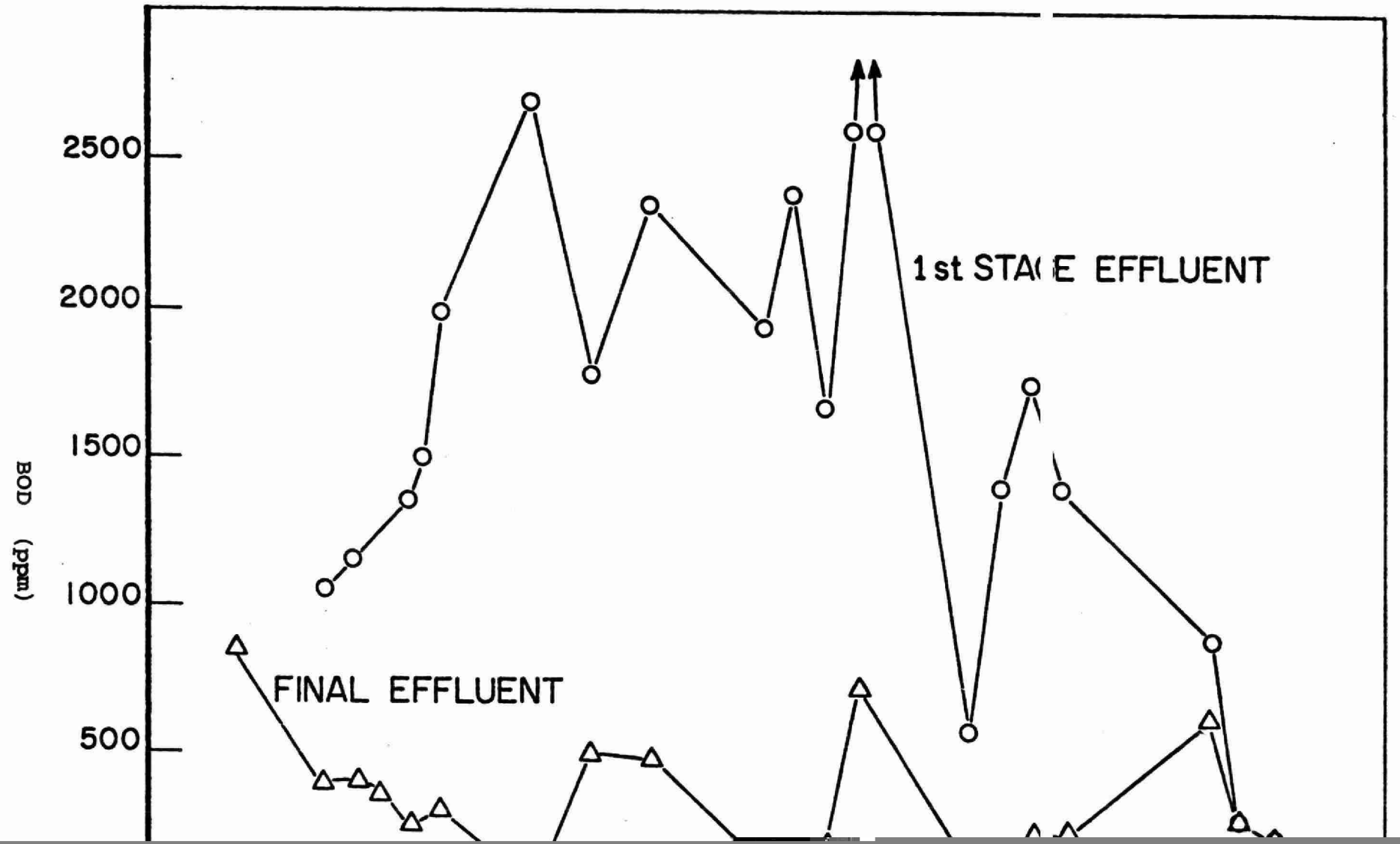


FIGURE VI. TWO STAGE BIODEGRADABILITY STUDY


2500
2000
1500
1000
500
BOD (ppm)
1st STAGE EFFLUENT
FINAL EFFLUENT

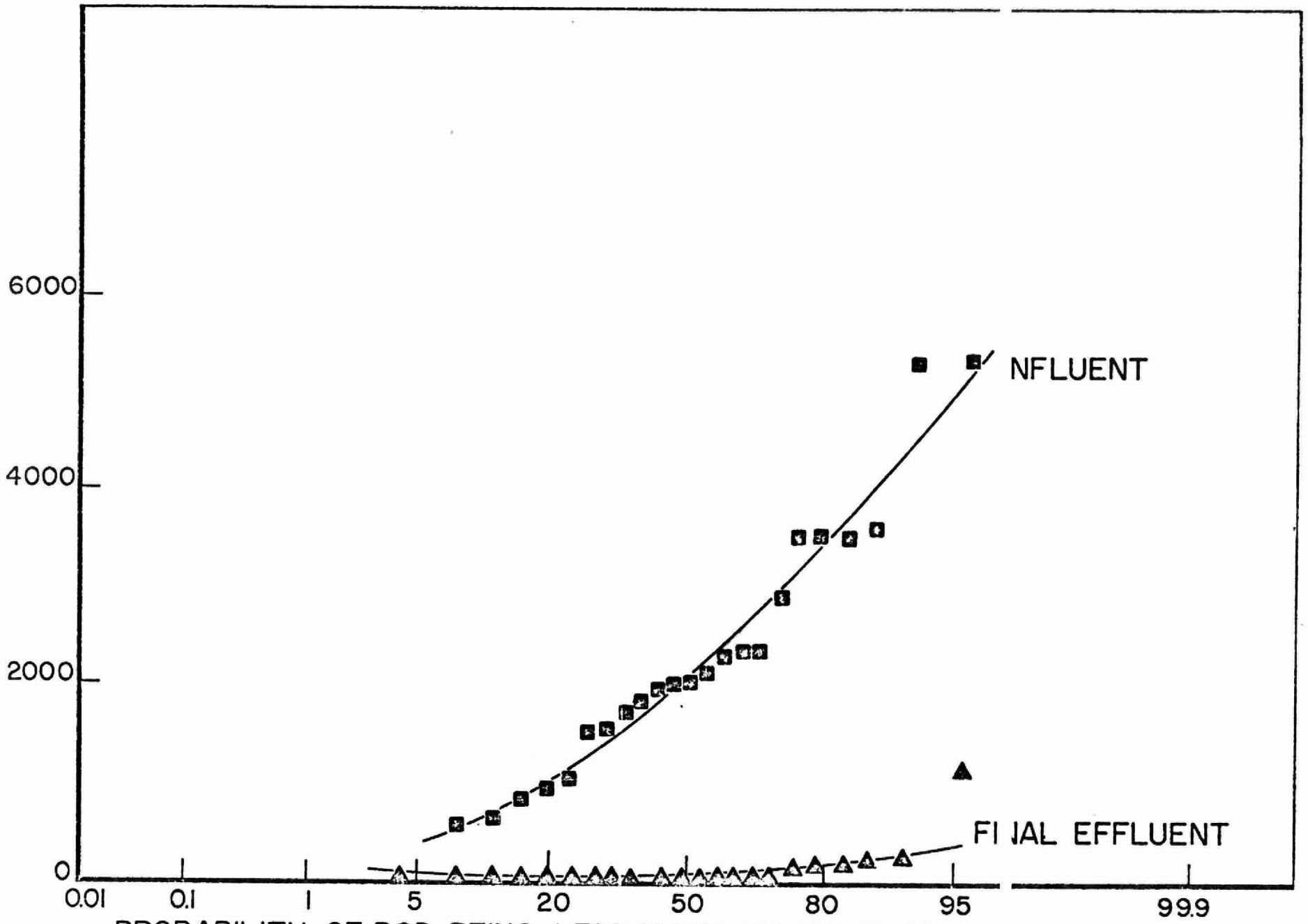


FIGURE IX. TWO STAGE PLANT INFLUENT AND EFFLUENT – BC D CONCENTRATIONS

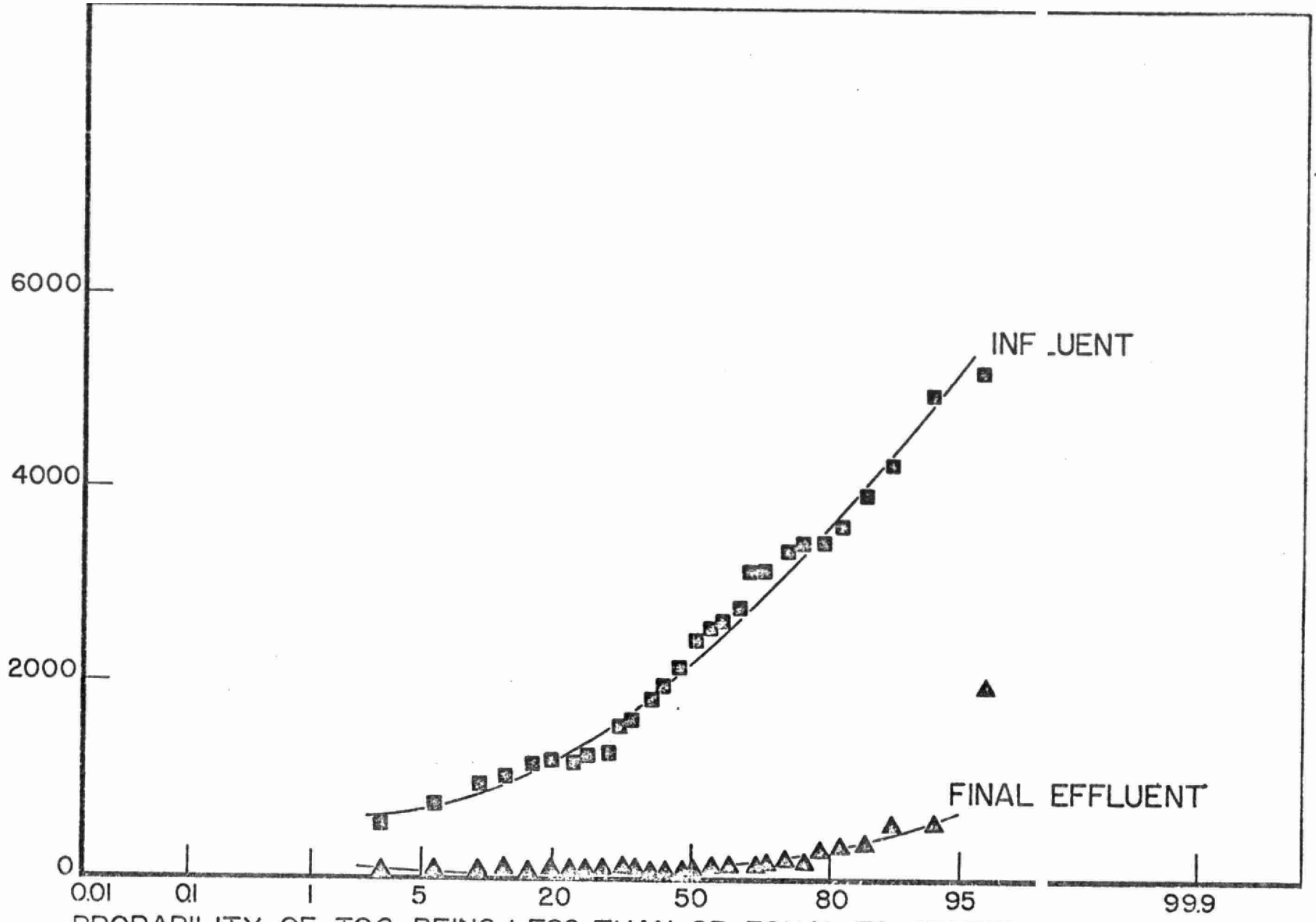


FIGURE X. TWO STAGE PLANT INFLUENT AND EFFLUENT – TOTAL ORGANIC CARBON CONCENTRATIONS.



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WATER POLLUTION CONTROL AT A MULTI-PRODUCT ORGANIC CHEMICAL PLANT - A CASE HISTORY

BY

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K. C. Bradley

This paper is in four parts:

1. Historical Background and Problem Developments.
2. The Beginning of a Trend of Significant Improvements.
3. A Period of Setbacks, Frustrations and Promises.
4. Current Difficulties and Our Program for Dealing with Them.

1. A Brief History of Problem Developments

Our plant is located in Elmira (pop'n. 4,600) - Township of Woolwich, 14 miles North-West of Kitchener-Waterloo, on the west bank of the Canagagigue Creek (fig. 1). This is a small tributary of the Grand River, designated for agricultural use, and running through the east side of town.

The Canagagigue Creek flow approximates 15 or 20 million imperial gallons per day, but varies from an estimated 2½ to 4½ million per day during a dry summer to well over 40 million imperial gallons per day for a good part of the spring months and occasionally during a wet fall. Of this flow, almost 1 million is contributed by clean cooling water from wells discharged from several of the more than 20 outfalls

at the UNIROYAL plant. Any problems with this waste water are minimal and will therefore not be referred to in this discussion. Another 450,000 imperial gallons per day comprises the treated waste waters from the Town of Elmira and from UNIROYAL's contaminated aqueous wastes directed to the joint UNIROYAL:Town activated sludge water pollution control plant.

The Elmira plant was started up in 1941 as a chemical producer for Allied War Supply. After the war, production was diversified into rubber, agricultural and miscellaneous organic chemicals. This brought the need for a full-time waste control engineer. Increases in production and further diversification resulted in overall multi-product short run operation. The non-specialized multi-purpose equipment required, provides less than ideal manufacturing conditions, often lowering yields and increasing wastes. This is the key factor in seeing our waste control staff growing to its present size of five full-time members.

Papers presented at the third[1], fourth[2], and fifth[3] Ontario Industrial Waste Conferences described techniques in use and under consideration into the late 1950's. These included the accepted practices, at that time, of burial of non-aqueous wastes and discharge to the creek of certain process aqueous wastes after settling in lagoons or ponds. Inert lagoon sludge was even used at that time for building up low land.

In 1957 when the Ontario Water Resources Commission Act was passed, the need for additional treatment of waste water both by the town and UNIROYAL was recognized. The company was directed to submit plans for waste treatment and before the final design for our joint Town:UNIROYAL water pollution control plant was established, my predecessor, Ross Mills (now with the Canada Centre for Inland Waters in Burlington), had done a lot of good work showing the bio-degradation of chlorophenols[4] and other nuisance materials with a Dow-Pac trickling filter pilot plant and later with an Infilco Aero Accelator high-rate activated sludge unit.

The system eventually chosen to treat the combined sanitary sewer wastes from the town and contaminated aqueous wastes from UNIROYAL (which for greater ease of presentation will just be referred to as UNIROYAL wastes) was a conventional four chamber plug flow activated sludge treatment plant which is now operated almost as a completely mixed extended aeration type system (fig. 2).

A lack of sufficient holding and equalization capacity for UNIROYAL wastes caused water pollution control plant (WPCP) upsets during 1965 and early 1966. A 180,000 imperial gallon balancing tank was originally intended to provide UNIROYAL with sufficient (24 hour) equalization capacity. In 1966 the present equalization basin system was constructed to enable better biological treatment in the WPCP. See again lagoons in fig. 1.

In 1968 a waste control laboratory was built for the exclusive study of problems of pollution control. We have had as many as one dozen lab scale continuous flow-through activated sludge treatment units (fig. 3) in operation at one time in that lab demonstrating everything from treatability of individual process waste streams to combined waste water effluent quality of units in series at various detention times.

In the neighborhood of 50 technical studies have been completed to date by our people working in that one lab in the last five years.

Also in 1968 facilities were constructed for steam heating the neutralized aqueous wastes during the winter months. This helped winter operation of the WPCP, mainly by minimizing the ice build-up on the large primary clarifiers; however interesting BOD removal vs aeration section temperature effects were uncovered in the process (fig. 4).

In 1969 the equalization basins were cleaned out and clay-lined, and mechanical mixers were added to provide even better equalization. The waste water detention time was now approximately 10 days. At this time too the process of land disposal of solid wastes and tars on UNIROYAL property was terminated and contaminated soil and sludge was excavated and deposited in pits lined with an impermeable, non-degradable membrane. These pits were then covered with soil. The ground water has been sampled regularly ever since from 10 strategically located wells and previous evidence of possible early contamination is gradually diminishing. Two new clay-lined pits were constructed in 1970 in an area previously containing contaminated soil. These are used for wastes requiring additional pretreatment and if necessary for holding back excess wastes during the difficult treatment periods of January or February.

Up until about this time we had, I would say, the mistaken impression that the WPCP was not meeting its effluent quality objectives mainly because of problems of inadequate equalization and some occasional toxic or inhibitory organic materials. Also, new product additions plus the complex and changing schedule of production made diagnosis of the overall problem most difficult. Thus a lot of effort was devoted to correction in these areas. During 1959 very high treatment plant effluent BOD's with no real biological upsets led us to suspect organic overloading. Yet our waste water BOD directed to the WPCP still did not exceed the plant's so-called BOD design capacity. When a few 30 day BOD's were run and found to approximate three times the 5 day BOD values of our wastes, we did considerable work on determining the degree of additional biological pretreatment required. This involved running several sets of lab units in series at various detention times over a period of several months. As we were trying to degrade biologically many wastes from the production of biocides, it would seem we just didn't properly understand this situation. In that period we generated and sorted through an immense accumulation of biological oxidation data. Much of it we tabulated and ran through a computer to condense into basic truths. For example in our case we suggest utilization of as high an MLSS level in the WPCP as possible to get maximum biological oxidation, and in fact this is what is now being done. Another thing we learned which led us finally in the right direction and which we still believe was not too far off the mark was the conclusion that to completely solve the problem of high BOD's biologically, a pretreatment plant with an aeration section roughly 1½ times the size of the entire existing joint UNIROYAL:Town of Elmira WPCP aeration chamber was needed.

2. The Beginning of a Trend of Significant Improvements

Fortunately as an alternative to bio-oxidation we were looking into recycling and separation for concentration and outside disposal. Of even greater good fortune we found that the Goodfellow Group in Corunna could handle the material we had separated out and sampled to them.

Generally the cheapest and easiest solution to a waste control problem is found at the source. For this reason the process engineer is the man most able to bring about effective solutions. Mainly through the efforts of the process engineers we were able in the spring of 1970 to drum off for outside disposal everything previously discharging to our process waste water sumps with a COD concentration of 100,000 mg/l. or higher. We are still engaged in this type of program and presently we are even shipping out wastes of moderately high strength as low as 40,000 mg/l. COD. Others we are recycling until the concentration is such that outside disposal is economically feasible. The early results of this exercise were quite dramatic. The graph fig. 5 and table fig. 6 in the appendix to this paper illustrate the effect of this approach. Not only did remaining concentrations drop off, but successes in waste water recycling began to show up in reduced discharge volumes.

During the summer of 1970 the entire equalization basin system was neutralized and seeded with activated sludge. Some bio-oxidation has occurred ever since. An additional benefit was the lessening of our continuous pretreatment neutralization operating problems.

Our major volume reduction however came about in rather interesting fashion. Whenever the WPCP would experience severe problems of biological malfunctioning, we would be requested to restrict our discharge volume. This caused us to cut back on fresh water usage and our ponds would fill with more concentrated wastes. On the surface this might not seem like an appropriate solution, but the increased mixing and detention time in our pond system lowered the COD and its fluctuations and aided the operation of the secondary treatment system.

It is not uncommon to hear these days how a company required to devote more attention to pollution abatement found a savings through material recovery and water conservation. But what we don't often hear is the capital outlay required to effect such savings. In our case, the costs far exceed any savings in water and other material costs. For example the conversion of a standard barometric leg condenser system to a surface after-condenser (fig. 7) or inter-condenser system cost us several thousands of dollars and although this reduced our volume of contaminated aqueous waste significantly, no savings in total water usage or other materials resulted.

In general our savings are restricted to minimizing additional costs such as in re-use to lower the volume and costs of waste waters shipped to outside disposal locations. One entire process waste water is currently being deep-welled at a considerable shipping cost. In our efforts over the past five years to avoid this costly solution all we have managed to accomplish so far has been to cut the volume in half. We are aware that deep well disposal may shortly be unavailable, but

we have not yet found an economic alternative and we may just have to cease production of this material. On the other hand, with another group of products our Development Department has discovered a way to eliminate virtually all process waste waters.

Our new product development program requires that we determine and assess the biological treatability of all resulting aqueous wastes of any new product. With the heavy emphasis we have been placing on recycling in the last few years, I have seen a process flow diagram of one new product undergo two waste volume revisions within one year. Initially the process showed 26 lbs. of waste water per lb. of product. When we first obtained samples for biological treatability it had been revised to 8 lbs./lb. and finally to 4 lbs./lb. all within one year and even before the complete treatability study was concluded. Most of our processes however, seem to offer little opportunity for major waste volume reductions.

3. A Short Period of Setbacks, Frustrations, and Promises

Several years of work went into lab studies of solvent extraction, hypochlorite oxidation, ion exchange, and ozonation of various process waste streams with virtually no signs of encouragement. It seemed that by the middle of 1970 we had done all the easy things and we still had many big problems. Pressed to do something about the dark colour resulting from one of our major production items, we eventually settled on alkaline chlorination as an intermediate solution (fig. 8). This followed comparing results from treating with fly ash, activated carbon, ozonation, and heat treating with settling. Alkaline chlorination is regarded here as an intermediate solution only because of the somewhat poorer treatability of the oxidized product, the still fairly high organic content, and the fact that colour removal, although significant, is still not complete. We are currently working on total waste water recycling in this process and this technique now shows definite signs of promise.

One of the most interesting aspects of this material we sometimes call "contaminated aqueous wastes" is the fact that it is never quite the same. The product filtered from an aqueous medium may be virtually identical from batch to batch, but the properties of the filtrate seem to vary on occasion quite markedly. For example we have found toxicity of the waste water to certain organisms varying by factors of ten from one production run to another of the same material. Our research laboratory's pollution group in Guelph took on the problem of identification of toxic component(s) for us in one major process waste stream and now after a couple of years' work the answers appear to be coming in. Once knowing what it is, we can attempt to modify the chemistry of the process so as to prevent formation of undesirable by-products. While this identification work was in progress, we in Elmira worked to destroy it or remove it no matter what it was. Powdered activated carbon appeared to work nicely in the lab, but every plant trial failed and months of effort were lost trying unsuccessfully to find out why.

During the summer of 1971, production stopped for about two months due to a strike. Waste water was fed from our pond system to the WPCP at a reduced rate in an effort to maintain biological acclimation. Before the pond system was drained, the toxicity had all but disappeared. We reasoned that this may have been due to the increased detention time along with the bacterial action in the pond system, and so we set about repeating this in lab experiments. The lab studies not only confirmed this phenomenon but suggested that if we could double our basin detention time the toxicity, as we measured it, could on occasion be reduced by a factor of twenty or more. This gave us further incentive to achieve some success in our waste water reduction program. However, cutting the discharge volume to treatment facilities in half seemed at this time to be a rather unrealistic goal and other methods for toxicity reduction were investigated.

Following settlement of the strike and start-up early in September, problems with acclimation to our wastes appeared to be the reason for high levels of rising chunks and globs of activated sludge to float from the WPCP final clarifiers until near the end of November. Because of this problem our discharge volume was restricted to 33% of the pre-strike period. During this lengthy period of acclimation, the level in our ponds was rapidly nearing the top. Several brainstorming sessions among production, development, and engineering people resulted in enough additional recycling and clean water separation techniques to allow us to get through this critical period, but by the time we did balance the water in with the water allowed out, every pond was filled to capacity. Amazingly our "unrealistic" goal of doubling our basin detention time was achieved in only a few months time - and at a time of very high overall plant activity due to the general upswing in the economy following the economic stagnation during 1971.

For those of you who may come across a similar problem, I've listed some very important aids to accomplishing such a task:

1. Process engineers who know their equipment and processes, and can analyze the factors contributing to waste water flows. This is most important for re-routing clean water, recycling contaminated waters for other less rigorous consumption, and for using less water in general.

2. Material balance flow diagrams that include a water balance for each production process.

3. A waste water monitoring system that records discharge volumes and collects samples at selected locations through the plant.

4. A record of all production listed by location and date of production.

5. A periodic production schedule to allow forecasting future discharge volumes.

Just how valuable this system can be in solving very practical problems was illustrated to us early last spring when we found the waste water level in the pond system rising at a time when our records showed that it should be declining. A quick check back at the monitoring system

records showed an occasional unusually high pumping rate at one location where the production schedule in conjunction with flow diagrams indicated a much lower rate. The process engineer overseeing production in that location was called in and from his knowledge of the equipment in operation there at that time could not explain the high flow. Appropriate equipment was then shut down, the waste water sump was pumped out, and various lines were blocked off. The next day the sump was full and examination showed that an underground water line connection had been broken and was leaking into the ground at a varying rate. From here it was being carried away by the dirty water collection system. Without our monitoring system this leak would have gone undetected for a much longer period.

The importance of adequate record keeping and communications is illustrated in our next "unfortunate event" example. It occurred in 1969 when we cleaned out our basin system in preparation for clay lining. The settled sludge volume far exceeded the capacity of the area approved for disposal, but we didn't know this until the sludge removal operation had begun. We didn't know this because we hadn't any written record of the extent of the hidden island of sludge in the centre of the pond resulting from earlier attempts at clean-outs. However, as we were already in the process of cleaning out and filling in our series of pits and waste water holding ponds on the east side of the creek, we were able to deposit much of the excess sludge on top of polyethylene in one of these pits until more permanent disposal was arranged.

To lessen the chance of sludge build-up causing a problem again we are now installing in place of the existing primary settling pond two large concrete settlers to be used alternately for settling and sludge conditioning (fig. 9). In the interim, studies were conducted on filtration, centrifugation, flocculation, sludge dewatering with polyelectrolytes, and air drying in order to determine the most appropriate solids removal system. At this time the nearest approved disposal location we were aware of was 135 miles away, and it was important that the water content of the sludge be kept to a minimum to avoid excessive shipping costs.

In 1971 we realized that our pollution abatement efforts at the various sources were still going to be insufficient in allowing the WPCP to meet its effluent quality objectives. This was rather disappointing news since our BOD delivered to the WPCP was now in the order of 1/5 of the WPCP's design standard share allocated to UNIROYAL wastes and only 1/4 of our 1969 level. As we had serious doubts from our many lab studies that the treatment plant would meet its objectives even without any of UNIROYAL's wastes, we set about looking into tertiary treatment with activated carbon. We did not initially consider carbon pretreatment because it seemed illogical to adsorb on carbon that which would be removed by the existing biological process. Also the receiving stream was expected to benefit far more from a carbon tertiary treatment application than from carbon pretreatment on UNIROYAL wastes. However the high cost suggested from our initial work for a tertiary treatment application, whether it be by powdered or granular carbon, led us to experimentation with a pretreatment application. Interestingly we found that our readily bio-degradable organics were not nearly as strongly adsorbed as the refractory and inhibitory materials, and the cost of such

pretreatment appeared to be much less. In addition we were encouraged to work in this direction by the Industrial Wastes Branch of the Ontario Ministry of the Environment.

During the same period of study our research lab pollution abatement group came up with an alternate solution involving complete recycle of UNIROYAL Elmira plant aqueous wastes. This concept was based on evaporation and fluid bed incineration by the Copeland process. Having two solutions and finding that both should work was a novel experience for us. Because the cost structure of each was so different, we felt obliged to present our recommendation to management with the supporting economic analysis. I include this (see fig. 10 - hypothetical data) to demonstrate the difficulties one can encounter in trying to determine the economic choice. One may be a lot cheaper than the other, and if so, which one? Even if you have all the estimated cost data you still can't always be certain which is the cheaper alternative unless you have a feeling for your company's present and expected future cost of capital.

4. Current Major Technical Difficulties and the Program we Have For Dealing With Them

In addition to the usual puzzles, the complexity of problem solving is, for us, further magnified in several ways:

1. Small production runs require multi-purpose equipment. This increases unit production costs over long production runs in specialized single purpose equipment. Yields may also be lower, often resulting in more wastes.

2. Pollution control techniques are generally cheaper per pound of material processed as equipment size and quantity of processed material increases. Some examples are: incineration, evaporative desalination, freeze separation, solvent extraction.

3. Many product processes require unique treatment facilities. This also increases treatment cost per pound of product.

4. With a multi-product plant, any change in effluent requirements may well cause as much in-plant re-thinking in each of many product areas, and will require more expertise to be applied, than in any single product plant with one effluent problem.

5. In late 1972 new more restrictive objectives were prescribed for the Elmira WPCP effluent. See fig's. 11 and 12.

6. Because much of the central part of our plant was erected over 30 years ago, fewer choices are presented in dealing with disposal practices. We do, however, have a very successful program, involving all our employees, to minimize yard run-off or spill problems.

Currently, as we see it, our water pollution problems are these:

1. The receiving stream is small and has a very limited assimilative capacity.

2. The receiving stream has been designated for agricultural use.

3. Our pretreated waste water contains bacteriacides, slimicides, fungicides, and other materials both inhibitory and refractory to activated sludge treatment.

4. Our waste water is highly variable; it contains complex organics and it contains a great number and wide variety of them.

5. Future characteristics of the raw waste water are to a certain extent unpredictable (due to multi-product, multi-purpose nature of our plant).

6. The colour of our wastes is high and deepens on further bio-oxidation.

7. The level of inorganic salts in our waste water is high.

To attack these problems we are organized as follows:
We have a - Pollution Control Management Committee consisting of:

1. Factory Manager
2. Development Department Manager
3. Engineering Department Manager.

The responsibility of this committee is to approve and direct the pollution control program from which specific projects will be recommended to our general manager for funds. To support the Management Pollution Control Committee we have the - Pollution Control Technical Group which consists of:

1. Plant Waste Control Co-ordinator
2. Production Superintendent
3. Senior representative from the Engineering Department
4. Chemical Development Section Manager
5. Senior Chemist - Pollution Control.

The Technical Group is responsible for:

1. Identification of the pollution problems.
2. Collection of data for evaluation of priorities for problem studies.
3. Agreement on the objective or goal and experimental procedures to find possible solutions.
4. Recommending to the Pollution Control Management Committee by written reports including technical data and economic evaluation, the best alternative solution to the problems.

As one part of the mechanics of control, we have drawn up a "Time-Logic Network" extending over a period of several years. On it we have listed all the individual pollution abatement projects with their expected completion dates. From this and product sales forecasts, we attempt to plot ahead the combined effect on our discharge to the WPCP. Regular meetings are held to review the progress and where necessary to recommend to the Pollution Control Management Committee, re-allocations of human resources based on this progress. We have found this very helpful in keeping individual projects from lagging behind.

Other control mechanisms involve: (a) our use for many years of a spill report form for correcting situations leading to hazards from spills, (b) our use of films, seminars, and meetings to continually up-date our people in the latest pollution abatement practices, and (c) the co-operation of all the employees and the Union as part of our program in finding ways and means to reduce wastes.

With this organization I feel that we are well on our way towards showing another year of significant progress and eventual problem solution in the not too distant future. For the very near future we see improvements due to current efforts in recycling process waste waters, and in changes of process chemistry where more costly substitute chemicals may be used to generate products with less difficult to treat wastes. Also, we feel very enthusiastic about activated carbon for those residual non-biodegradable organics escaping all other upstream pretreatment efforts, and in this regard we feel we have the finest automatic, moving, expanded bed, granular activated carbon pilot adsorption unit built, figs. 13 and 14. This is the type of system that lab column studies have demonstrated effective for our particular situation. Our pilot unit has now confirmed this, and at this point in time, we fully expect to construct a full-scale treatment system.

In summary our intensified efforts of the last 3 years have been rewarded by the following progress:

1. Almost complete BOD problem solution by outside disposal of high strength aqueous wastes, re-use of process waters, process changes to reduce wastes, and further in-plant treatment (extraction, oxidation, additional settling, aeration, equalization, and bio-oxidation).

2. A cut in the WPCP final effluent BOD by almost 50% in each of the last 3 years.

3. A cut in the waste water discharge volume to the WPCP in half over this period while at the same time increasing production.

4. Seeing fish inhabit the stream immediately below the WPCP outfall.

5. Getting a long-term program underway to solve both current and future problems.

In closing may I express the hope that some of you may find here some useful items for your own problem-solving applications.

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3. R. E. Mills, Dominion Rubber Co., Ltd., Elmira, Ont., Industrial Wastes Control at an Organic Chemical Plant, Fifth Ontario Industrial Waste Conference, 1958.

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ACKNOWLEDGEMENT

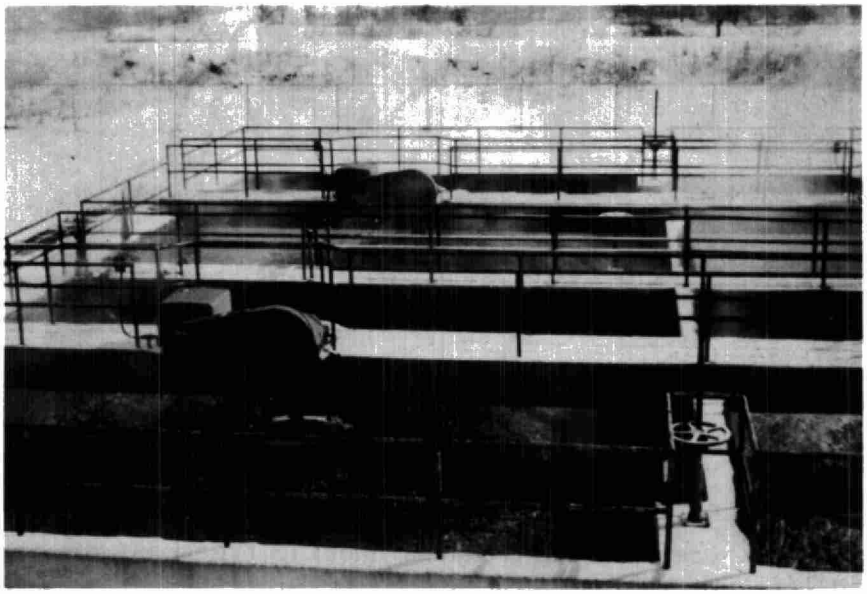
Many helpful suggestions in the preparation of this paper were provided by our Factory Manager, Mr. A. H. Gorman. This assistance is gratefully acknowledged.

Figure 1



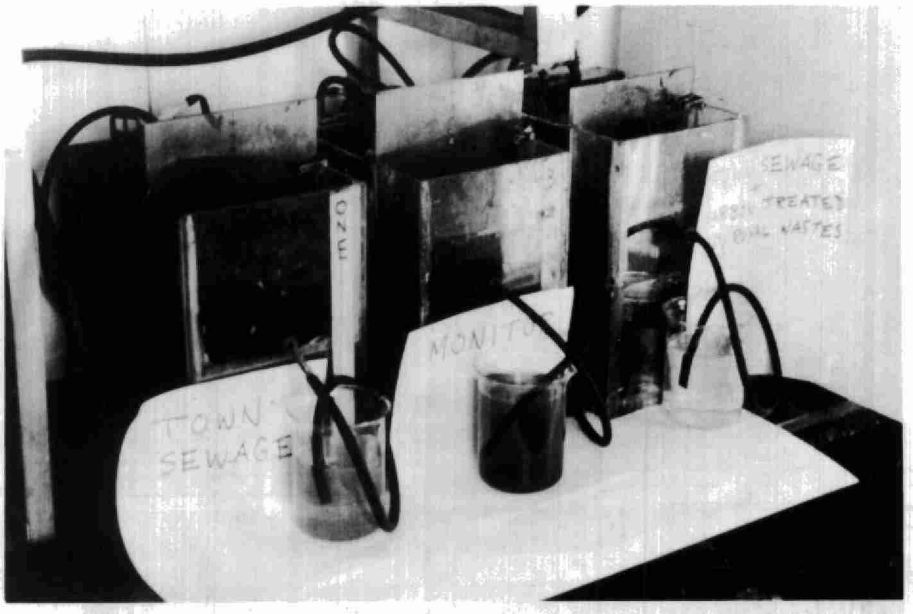
Aerial view of the plant showing east side of the town at the far left, UNIROYAL between the railway tracks and the river, UNIROYAL'S lagoon system on the left bank of the river, and a portion of the joint UNIROYAL:Town of Elmira WPCP centre bottom.

Figure 2



Two of the four aerators in the aeration section of the UNIROYAL:Elmira Water Pollution Control Plant (WPCP). Primary effluent flows equally into each of the four aeration sections. Sludge return is directed to the two shown, from the two valves at the left.

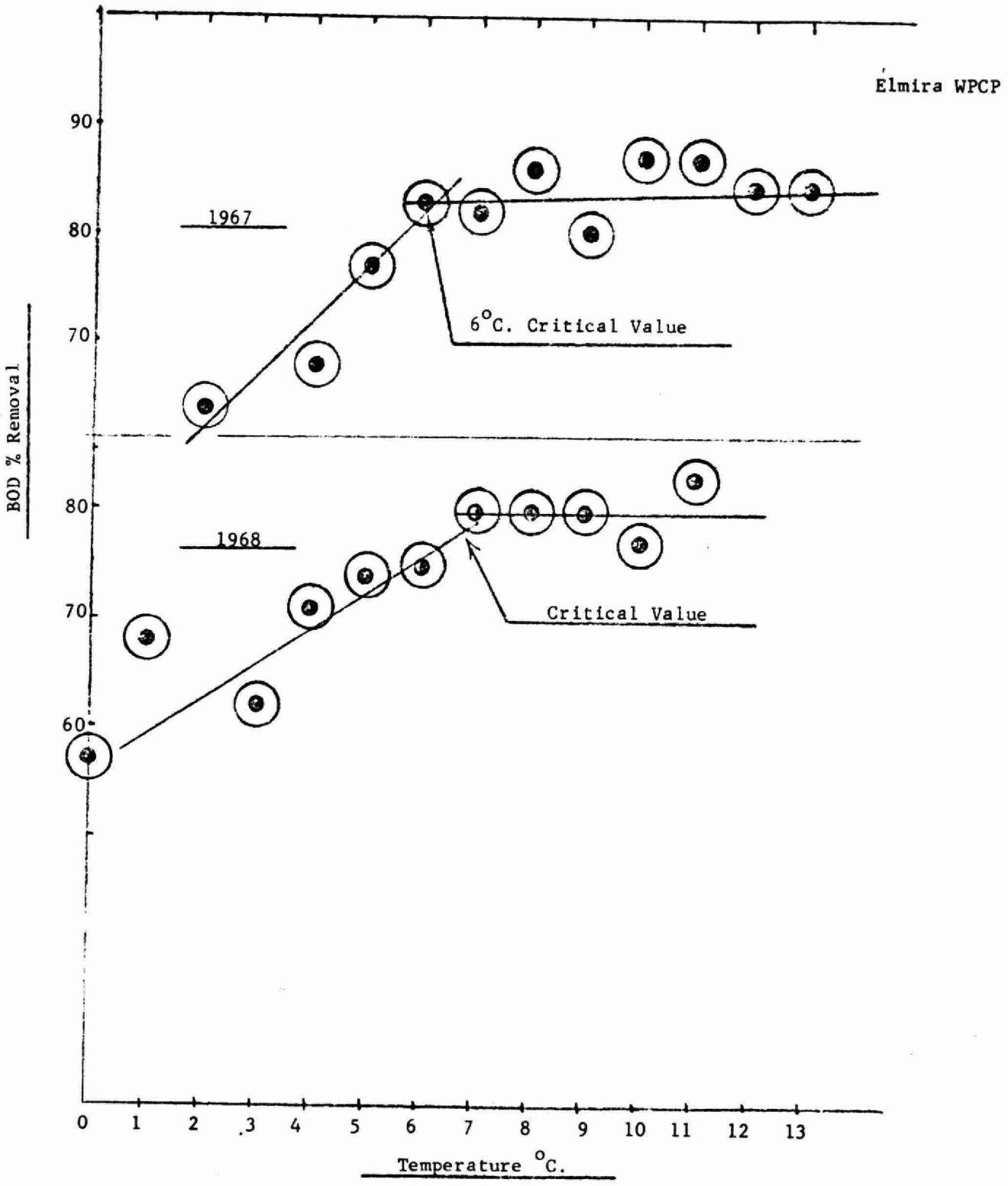
Figure 3



Biological treatability studies showing treatment of, from left to right, town sewage (TS), TS plus UNIROYAL wastes, TS plus carbon treated UNIROYAL wastes.

Figure 4

Temp. vs BOD removal by activated sludge



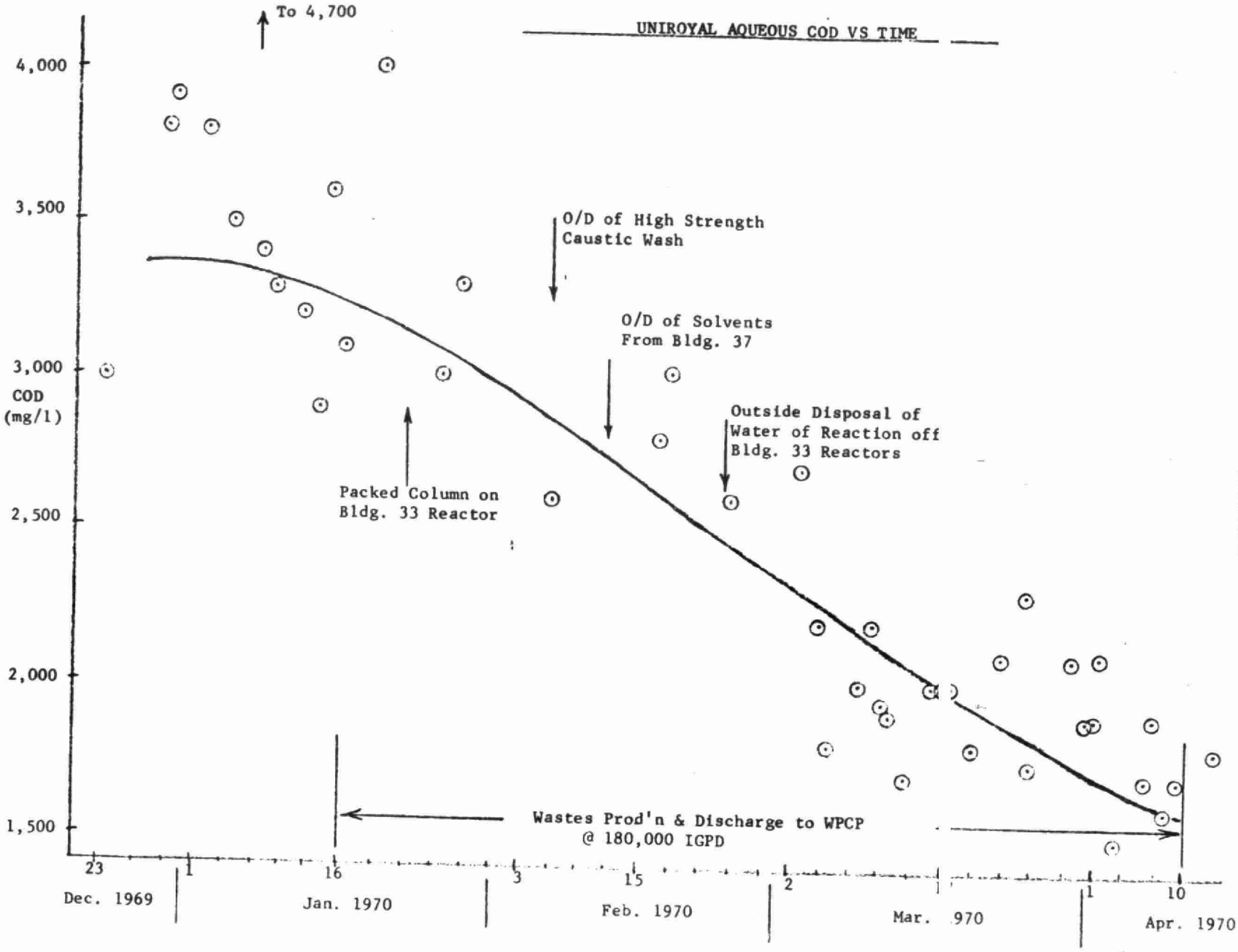


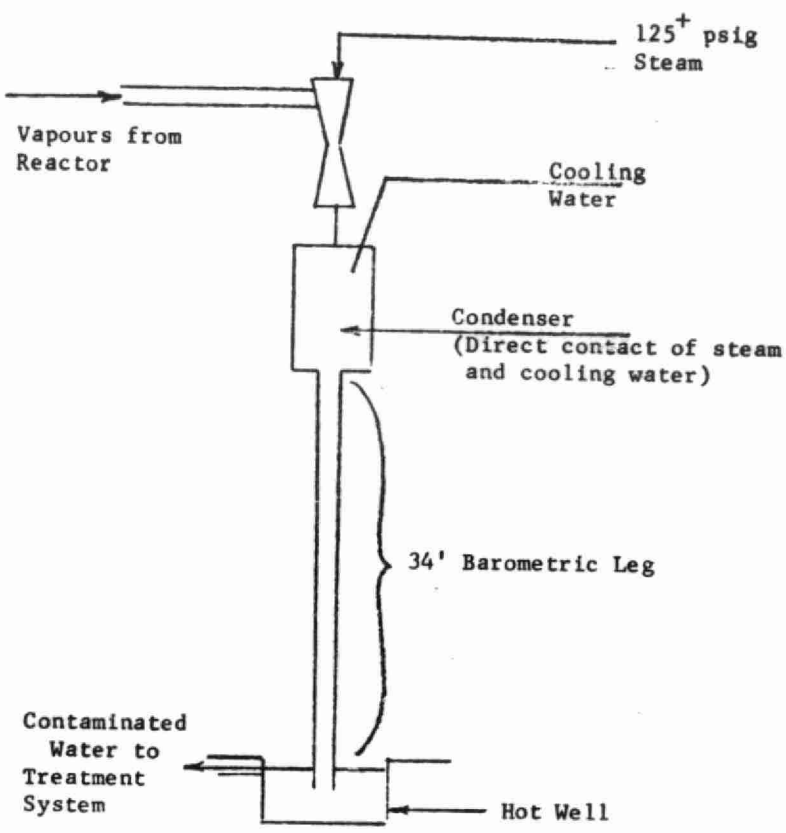
Figure 5

UNIROYAL AQUEOUS COD VS TIME

Figure 6

Year	UNIROYAL DISCHARGE TO WPCP COD (lbs/day)	ELMIRA WPCP FE BOD_5 (mg/l)	
1965	1250	77	
1966	2400	61	
1967	2500	44	
1968	3000	58	OBJECTIVE
1969	4700	107	15 mg/l
1970	2400	60	
1971	1950	31	
1972	1230	17	
1973	est. 1200	est. 15	(NEW OBJECTIVE 8-10 mg/l)
1974	est. 900	est. 13	

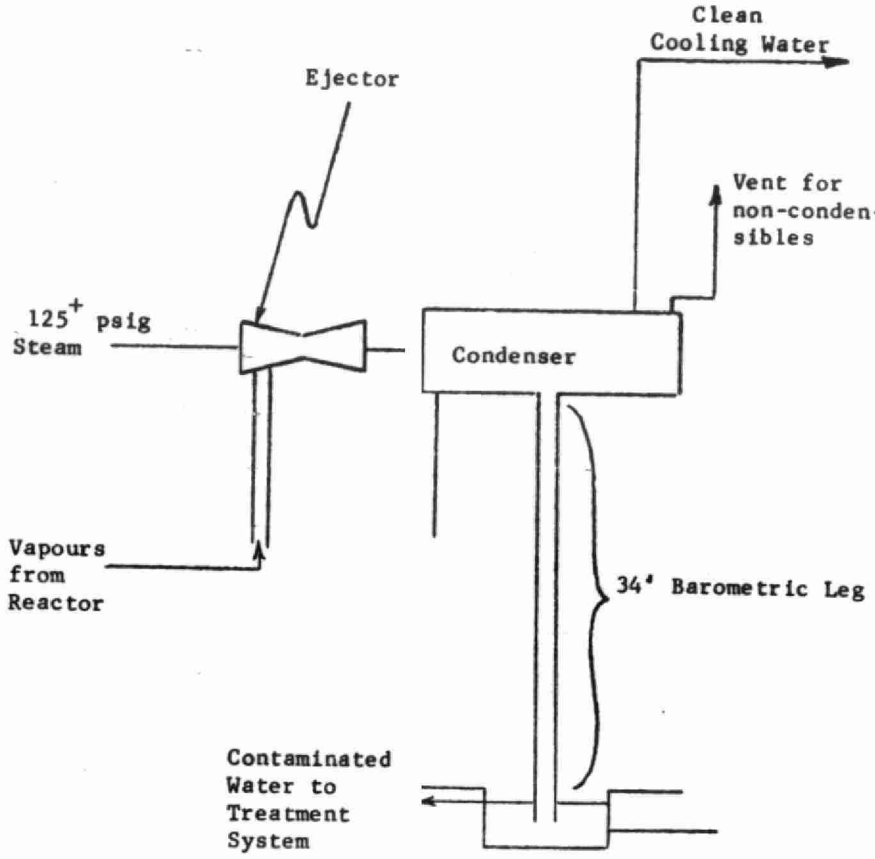
1. Barometric leg vacuum jet system



(30,000 IGPD)

~$10,000

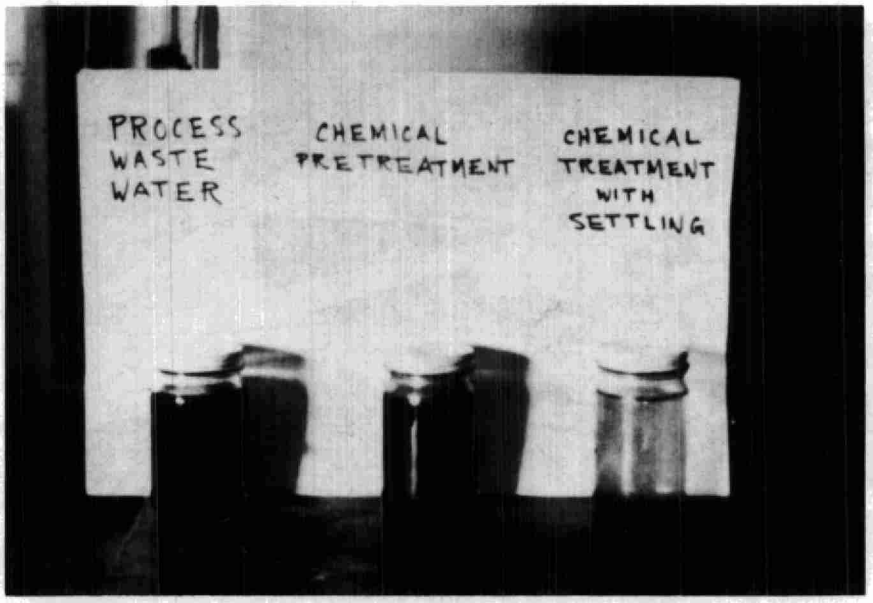
2. Surface condenser vacuum jet system



(1,000 I PD)

Figure 7

Figure 8



Colour reduction of a black process waste water through alkaline chlorination and settling.

Figure 9



Photograph showing the first new concrete primary settling pond with the old settling basin in the foreground.

At the right is a clay lined holding pond for process wastes requiring alkaline chlorination.

Figure 10

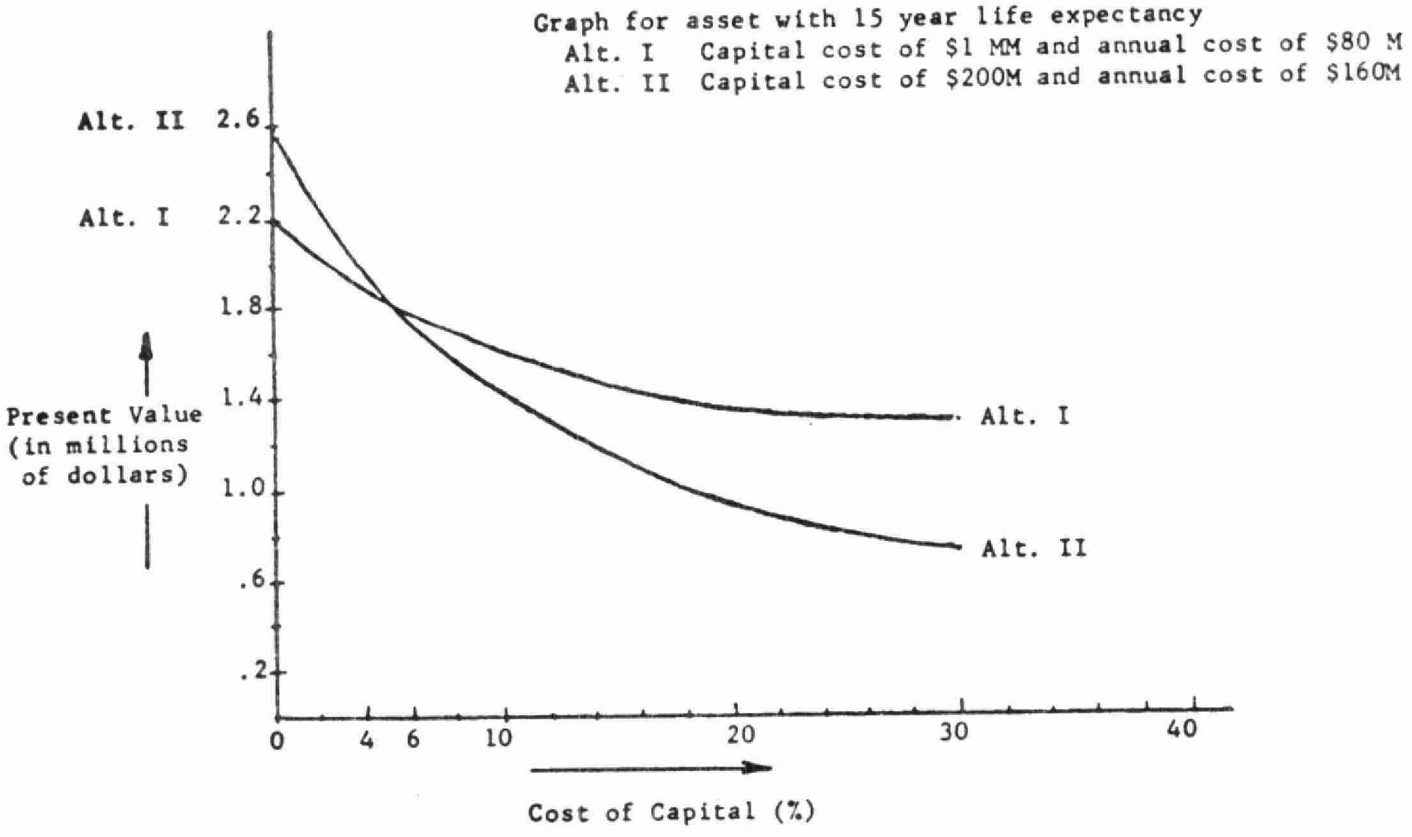

Graph for asset with 15 year life expectancy
Alt. I Capital cost of $1 MM and annual cost of $80 M
Alt. II Capital cost of $200M and annual cost of $160M
Alt. II
Alt. I
2.6
2.2
1.8
1.4
1.0
.6
.2
Present Value
(in millions
of dollars)
Alt. I
Alt. II
0
4
6
10
20
30
40
Cost of Capital (%)

Figure 11

ONTARIO

MINISTRY OF THE ENVIRONMENT

ELMIRA WPCP EFFLUENT QUALITY OBJECTIVES

(Partial List)

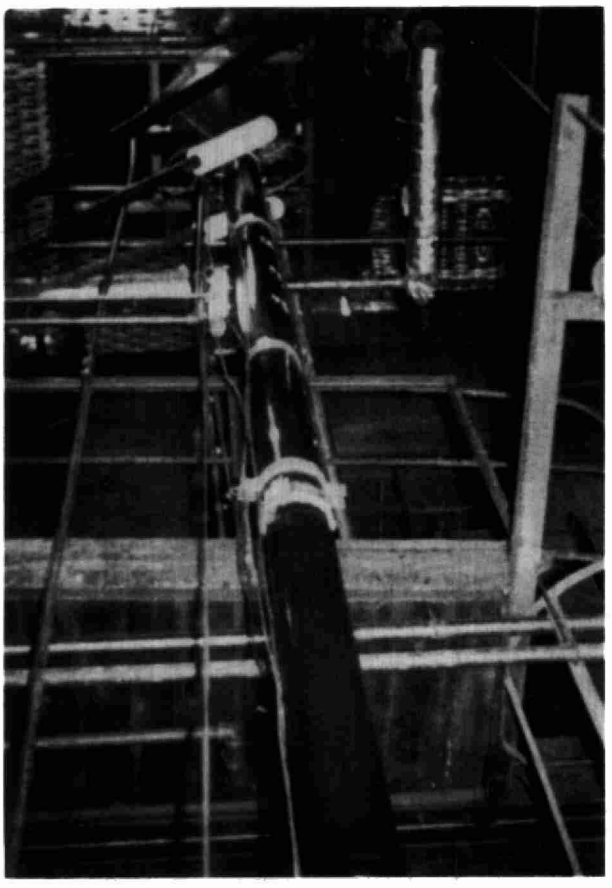
BOD_5	10 mg/1 max.
Suspended Solids	15 mg/1 max.
Phenolic Equivalent	20 µg/1 max.
Chlorides	1500 mg/1 max.
Sulfates	1500 mg/1 max.
COD	100 mg/1 max.
Colour	25 APHA

Figure 12

IN ELMIRA

10 mg/l BOD_5	-	approximates 3 gals./day of bio-degradable organic material
15 mg/l SS	-	approximates 70 lbs./day
20 µg/l phenolics	-	approximates 1 ounce/day
1500 mg/l sulfates	-	approximates 5 tons as sodium sulfate per day

Figure 13



Upper sections of 19 foot moving bed counter-current carbon adsorber pilot unit. Carbon feed hopper may be seen at the top.

Figure 14



Bottom of carbon adsorber showing continuous sampler at bottom left. Operator, co-op student R. C. Innis, is holding samples of column effluent and influent.

(Effluent from bio-treatability study of this waste water is shown in figure 3.)



D. Wells

BIOMONITORING OF PETROCHEMICAL WASTE WATERS

BY

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The term bioassay means an assay or test of life. The grandfather of pollution bioassays is the biochemical oxygen demand test. In chemical terms a bioassay can be regarded as a titration in which the toxicant is metered out to the test organism until some specific, defined, end point or response is observed.

Biomonitoring is a modification of the bioassay procedure in which some of the precision and control of the laboratory are substituted to gain the benefit of using an absolutely fresh, continually varying sample of trade waste collected and tested within the plant. Since biomonitoring techniques lack the precision of control and the reproducibility of laboratory bioassays, biomonitoring has become a neglected aspect of pollution testing.

Experimental designs for biomonitoring have to be flexible to suit local conditions such as the availability of electricity, waste water and dilution water. Experimental stations established sequentially along a river down stream of selected outfalls will provide a different type of information from examination of undiluted effluents at the source. Differences in design and the presence or absence of fish mortality will provide answers to such questions as:

1) Where did the fish die - station.

2) When did they die - time.

3) Who killed them - identification of the plant or operating unit as a source of the toxicant.

4) What did they die from - toxicant(s).

"Conventional bioassay procedures can evaluate only single samples taken at particular times. Continuous flow bioassays of single grab samples over a long period of time can be very useful, but do not solve the problem of transient variations." (Jackson, H.W. and W.A. Brungs, 1966).

Contrasted to bioassay, biomonitoring can be used to:

1) demonstrate the continuous suitability of an effluent for aquatic life.....

2) detect changes in the biological acceptability of the effluent itself.

3) detect changes in the effect of the effluent on the biota of the receiving water.

There is growing awareness in both government and industry that some type of biological effluent quality control will be necessary in order to help meet increasingly stringent water quality requirements. The Ministry has, over the past several years, devoted some effort to the development of such techniques.

BIOASSAY AND BIOMONITORING EQUIPMENT AND PROCEDURES

The most basic bioassay equipment consists of three medium sized aquaria, about two dozen goldfish, air stones and lines, an air pump, a suitable (preferably dechlorinated or non-chlorinated) dilution water and a 15-gallon grab sample of the water to be treated. Supporting measurements can be limited to temperature, dissolved oxygen and pH for such a rudimentary test. Five fish used as a control and five fish used in the waste for a 4-day exposure are sufficient for initial testing. This elementary test can be expanded to multiple test concentrations run on a single grab sample, on a composite sample or on a continuous sample. If a continuous sample and multiple concentrations are used then provision must be made for pumping the waste to the testing site, for temperature control on the waste and dilution water and for suitable proportioning equipment.

There is a variety of equipment and methods that can be used to provide the variety of dilutions needed for biomonitoring. None of the equipment utilized to date can be considered to be ideal.

Proportioning pumps and multichannel, peristaltic pumps have been used with some success. These devices have several serious shortcomings. Firstly, small volume pumps of this type are prone to plugging. Secondly, should the flow of dilution water stop, the waste delivery pump continues dosing the exposure tanks perhaps killing the fish. Thirdly, calibration of the various channels against the dilution water flow can be an extremely time-consuming and frustrating experience.

Another proportioning device that has been used with some success is that developed by the State of Michigan for exposures of fish to various trade wastes (Wuerthele, M. 1971). This technique consists of two head tanks, one filled with the toxic feed stock and the other with dilution water. Out of the bottom of each tank are a number of tubes which when taken in various combinations give a variety of concentrations of the toxic feed stock. The major drawback with this technique would seem to be settling of particulate matter in the waste water head tank.

Another device which has been used for long-term industrial waste bioassays and growth and hatchability bioassays is the proportional diluter developed by D.I. Mount and W.A. Brungs in 1967. This device automatically proportions fixed volumes of dilution water against fixed volumes of a toxic feed stock. Rather than providing a constantly flowing series of dilutions of waste water the proportional diluter provides batch dilutions about once every minute. The diluter has the advantage of being easily calibrated and very stable in its calibration and delivery rates. The major disadvantage is that it cannot provide a dilution series beyond about one order of magnitude.

Whichever device is selected or devised for metering in the toxic dilutions it should be capable of discharging at each concentration at least four to six times the standing volume of the exposure chamber in a 24-hour period.

Once the temperature of the toxic feed stock and dilution water can be controlled and the two mixed accurately and reliably the next step is selecting exposure chambers for the test animals. For small fish, glass aquaria are probably the best choice. Small stainless steel tanks can also be used and are especially desirable in holding organic wastes. For large numbers of small fish or very large fish, exposure containers of 100-300 gallons are needed. Such containers are available at moderate cost in either polypropylene or fiberglass. Stainless steel can be used but at considerably greater expense. Glass aquaria are suitable for virtually any type of trade waste or toxicant. Stainless steel is best suited for handling organic wastes and various organic chemicals because problems of absorbtion, adsorption, desorption and cross-contamination are largely minimized. Low pH can cause some corrosion and leaching of heavy metals from stainless steel. Polyethlyene, polypropylene or fiberglass containers are best suited for handling largely inorganic wastes, heavy metals or low pH wastes.

Basic instrumentation needed for a biomonitoring project includes thermometers, dissolved oxygen apparatus and pH measuring equipment. Specific chemical analyses can be added as necessary. Recording pH and dissolved oxygen meters can be very useful.

All of this equipment can be housed in a mobile laboratory, an effluent testing laboratory or effluent treatment building. Wherever the project is set up access to it should be limited as tampering, pilfering and poaching can be a problem.

In the initial stages of an industry biomonitoring or bioassaying its own effluent the gold fish (Crassius auratus, L) is a good reliable test animal to use. Guppies (Lebistes reticulatus, Peters) are also reliable test animals.

Rainbow trout (Salmo gairdneri, Richardson) available commercially from numerous private hatcheries are somewhat more sensitive than either gold fish or guppies and generally should be tested at a lower temperature. Fathead minnows, (Pimephales promelas, Rafinesque) are common throughout Ontario but are rarely available in sufficient quantity or quality to be used in an industrial laboratory.

Commercial live bait dealers would appear to be a good source of small, live fish. Frequently, however, bait minnows which are usually a mixture of small species are held under less than ideal conditions and are not suitable for bioassay work.

The following two case studies are presented in which two different biomonitoring approaches have been successfully applied to the petrochemical industry.

CASE STUDY I

During the period July to December 1971, studies were developed to assess the waste water from a complex petrochemical plant and its effects on fish and receiving water.

DESCRIPTION OF THE STUDY AREA AND METHODS

Effluents entering the river upstream at the plant included a primary sewage treatment plant effluent and storm sewers and waste water from a large oil refinery and petrochemical plant. (Table 1).

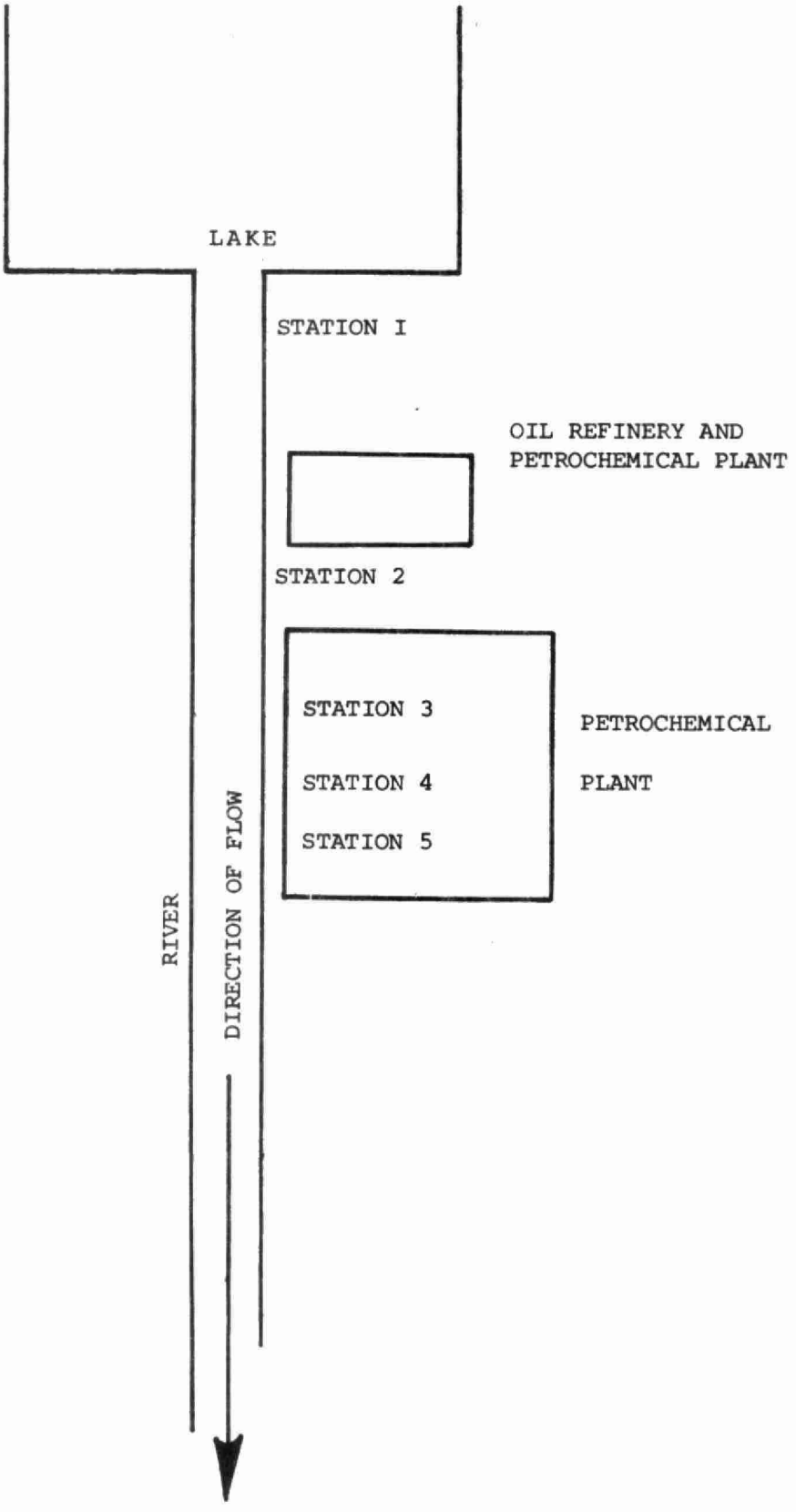
The field program involved retaining fish in five tanks located along the river bank down stream of specified waste discharges. The river water was pumped through the tanks continuously for 12 weeks. Two of the fish tanks (stations 1 and 2) were upstream of the petrochemical plant property and three stations (stations 3, 4 and 5) were on the plant property. (Figure 1).

Table 1: CHEMICAL ANALYSIS OF THE ST.CLAIR RIVER

	P A R A M E T E R						
Station	B.O.D. ppm	C.O.D. ppm	pH	NH_4 ppm	Phenol ppb	T.O.N. 60 °C	Description
1	0.4	<30	7.6	0.02	2	27	Wee y, fishy, acid vegetation
2	3	<30	7.9	0.08	-	1778	Cab age, acetylenic, oil
3	4	<10	8.3	0.10	10	20	Oil , weedy, rubbery
4	12	95	8.1	0.2	-	1148	Oil , garlic, septic, musty
5	12	65	8.1	0.5	-	1075	Chl rine, acetylenic, tu pentine

Figure 1

CASE STUDY 1 - STATION SITES



Station 1 was a concrete live well owned by a commercial fishing company. Stations 2 through 5 consisted of a 300-gallon polyethylene tank, lid, pump and associated plumbing and wiring. The intakes for stations 2 - 5 were determined basically by mechanical logistics but also to allow for some estimation of dilution ratios. Once the experiment was underway a daily inspection included cleaning and adjustment of all mechanical components, measurement of temperature, dissolved oxygen (Winkler) and pH and observations on the general health, vigor and feeding behaviour of the fish. Since the experiment was intended to run for 12 weeks the fish were sampled for taste testing at six weeks and again at the end of the exposure period.

The fish to be used for taste testing were kept in a deep freeze until the day before testing. When the fish were to be prepared for testing six samples were taken from each fish and cooked individually in tightly covered aluminium baking cups. The taste panel of six people gave the samples a rating of 1 through 4, the former indicating no unusual flavour and the latter strong, unusual flavours.

RESULTS

FISH TAINTING

Fish flavour evaluation studies indicated that after 40 days of exposure to the water at station 1 the fish were not tainted while those of stations 2, 3 and 4 were definitely/strongly tainted to the 99.9% level of confidence. Similarly, after 80 days of exposure the fish of station 1 were not tainted while those of stations 2, 3 and 4 were definitely/strongly tainted to the 99.9% confidence level. The trout at station 5 were definitely/strongly tainted at a confidence level of 99.9% after 11 and 23 days.

Chi-square analysis showed no significant difference between the 40- and 80-day exposure for stations 2, 3 or 4 or the 11- and 23-day exposure for station 5.

Using station 2 as a control for stations 3, 4 and 5 no significant difference in the intensity of tainting between these stations was demonstrated. (Table 2).

Spills and Unusual Discharges

Table 3 summarizes some of the major and minor spills and slug discharges at stations 4 and 5. Of the 19 incidents listed five were detected through visible changes in the effluent, another five were detected through resulting fish kills, eight were detected through pH monitoring and one (December 7) through other manifestations.

The spills and unusual discharges noted at station 4 were shown by extreme fluctuations in pH and the occasional fish kill when preventive, protective action was not taken. These pH disturbances arose exclusively in one area of the plant. At station 5 discharges from a unit handling crude benzene predominated in frequency and severity.

Table 2: Incidence of foreign flavour in rainbow trout samples. 40-day exposure.

Station	# of Samples	FOREIGN FLAVOUR 1	2	3	4	TOTAL Pos.	Definite Strong
1	72	58	13	1	0	14	1
	% 100	81	18	1	0	19	1
2	72	0	5	24	43	72	67
	% 100	0	7	33	60	100	93 *
3	72	6	8	34	24	66	58
	% 100	8	12	47	33	92	80 *
4	72	0	4	11	57	72	59
	% 100	0	5	16	79	100	95 *
5	30	0	0	4	26	30	30
	% 100	0	0	13	87	100	100 *
	36	0	1	12	23	36	35
	% 100	0	3	33	64	100	97 *

* Results significantly different from the controls at the 99.9% confidence level.

80-day exposure

1	72	62	8	2	0	10	2
	% 100	86	12	2	0	14	2
2	48	1	12	14	21	47	35
	% 100	2	25	29	44	98	73 *
3	102	6	34	35	27	96	62
	% 100	6	33	34	27	94	61 *
4	24	1	6	8	9	23	17
	% 100	4	25	33	38	96	71 *

* Results significantly different from the controls at the 99.9% confidence level.

On November 8, a mixture of styrene, benzene and ethyl benzene was discharged from the benzene unit to station 5. This discharge which lasted less than one hour resulted in the death of all fish. There was no damage to a polystyrene float supporting the water intake for this station. On December 7 a discharge of 1,100 gallons of similar material resulted in extensive dissolution and melting of the float. Styrene and ethyl benzene were measured in the sewer at 250 ppm and 80 ppm respectively. An analysis for benzene was completed but none detected.

Table 3 illustrates that under conditions of frequent observation more than 30% of the observed incidents resulted in dead fish. This value would have been much higher if preventive action had not been taken repeatedly at station 4. Such action included shutting off the water supply pump and adding fresh, domestic water or oxygen to the liquid in the tank.

Laboratory Studies - Fish Weight

Table 4 presents the average weight of the fish at various locations with increasing exposure time. It can be seen that fish from station 1 gained weight significantly while those of station 2 lost weight. Compared with their starting weights the fish from stations 3 and 4 did not change significantly during the 80 days. Owing to the impact of recurring lethal discharges necessitating replacement of fish it is felt that any weight difference noted in the fish of station 5 would not be a reliable index of their growth.

Comparing mean weights of control fish to the mean weights of fish from stations 2, 3 and 4, the control fish were significantly heavier after 40 and 80 days exposure. Using the Chi-square test of comparison and station 2 as a control against stations 3 and 4, the fish from station 3 were significantly heavier than the controls (station 2) but those from station 4 were not. Similarly, at 80 days exposure the fish of station 3 were significantly heavier than the controls (station 2) whereas fish from station 4 were not. These differences were due to the fact that the fish from station 3 grew slightly whereas the fish from station 2 lost weight, thereby increasing the difference between the two stations. The fish from station 4 lost weight thus minimizing any difference between station 2 (control) and station 4.

DISCUSSION

The river upstream of the oil refinery outfalls was shown to be relatively odour free. Based upon many field observations at station 1 the water quality is entirely suited to the maintenance of a healthy aquatic flora and fauna.

At station 2 there has been a rapid deterioration of water quality. The water at this station had a strong odour and a capacity to taint fish and to stunt their growth. Oil slicks are a constant feature of the river at this location.

While the fish from station 3 fed well, weight increase on the 80-day exposure period was negligible by comparison with

Table 3: Spills and Unusual Discharges

DATE	CONTAMINANT	AMOUNT OR DURATION	SOURCE SUSPECTED OR CONFIRMED	STATION AFFECTED
Sept.14	pH fluctuations	N.A.	Feed Prep area	4- Total fish kill
Sept.24	Low moll wt. isoprene	Estimated <50 I.G.	Butyl Unit	5- Mess on river bank
Sept.30	pH fluctuations	1.5 hrs.	Feed Prep area	4- Fish stunned but recovered
Oct. 1	Strong caustic	< 1 hour	Stereo Unit	5- No effect.
Oct. 1	pH fluctuations	2 hours	Feed Prep volt	4- Fish Tank pump turned off.
Oct.2	Hexane	17,000 Imp.gal.	Stereo Unit	5- Fish tank pump turned off.
Oct.3	pH fluctuations	1 hour	Feed prep unit	4- Fish stunned but recovered
Oct.6	pH fluctuations	1.5 hours	Feed Prep unit	4- Fish tank pump turned off
Oct. 14	Acetonitrile/oil emulsion	several hours	Butadiene Unit	5- Apparently no effect
Oct. 17	Water extract of crude benzene	< 1 hour	Styrene Unit	5- Total Fish kill
Oct. 22	pH fluctuations	14 hours	Feed prep unit	4- fish tank pump turned off
Oct. 30	pH fluctuations	1/2 hour	Feed prep Unit	4- Partial fish kill
Nov. 8	Mixture of styrene ethylbenzene and benzene	< 1 hour	styrene Unit	5- No damage to float. Total fish kill

Table 3: Continued

DATE	CONTAMINANTS	AMOUNT DURATION	SOURCE SUSPECTED OR CONFIRMED	STATION AFFECTED
Nov.10	pH Fluctuation	< 1 hour	Feed prepunit	4- Fish apparently unaffected
Nov.12	pH Fluctuations	2.5 hours	Feed Prep Unit.	4- Fish unaffected. Repair work on pH controller
Nov.15	Carbon black	< 1 hour	Butadiene Unit	5 -
22	pH Fluctuations	1 hour	Feed Prep unit	4 - Fish tank pump turned off.
27	pH fluctuations	1.5 hours	Feed prep unit	4 - Total Fish kill.
Dec. 7	Styrene, ethylbenzene etc.	Several Hours	Styrene Unit	5- Partially melted plastic float in river. Potentially lethal.

Table 4: Mean Weight of fish (gms) at each station vs. duration of exposure

Station	0	11 days		23 days		40 days		80 days	
		N	$\bar{x}$ wt.	N	$\bar{x}$ wt.	N	$\bar{x}$ wt.	N	$\bar{x}$ wt.
1	226**					12	284*	12	343*
2	226**					12	212	8	194*
3	226**					12	243+	12	+245*
4	226**					12	211	6	213
5	226**			14	228				
	284	28	240						

* Weight changes significantly different from starting weight at the 95% confidence level.

+ Weights significantly different from those of Station 2 at the 95% confidence level.

** Average weight of fish based upon an estimate of the hatchery population.

N Equals the number of fish measured at the end of each exposure period.

station 1 but significantly more than station 2.

The increase in fish growth from station 2 to station 3 can be accounted for by the increasing distance from the outfalls of the oil refinery and the additional dilution, mixing, volatilization and digestion provided by this distance.

Throughout the exposure period at station 4, one of the most notable features was the lack of feeding on the part of the fish. Food pellets offered to the fish were almost totally ignored. By contrast, a handful of pellets offered to the fish at station 1 would rarely reach the bottom of the tank. The lack of feeding at station 4 continued uninterrupted through periods when the pH of the 54"-sewer maintained at steady, near normal levels. The only time the fish at this station showed any interest in the feeding was for a five-day period (November 1-5) when the isobutylene plant was not operating and no process waste was being discharged to the sewer. The pH of the water in the fish tank at this time was at ambient river levels. Since the fish showed total indifference to the food pellets on which they had been raised they did not gain weight. Indeed, there was a loss of fat from the tissues of the fish indicating that they were living off energy reserves and would ultimately starve to death.

Another feature of the effluent monitored at this station was the extreme fluctuation in pH. At times, these fluctuations could be anticipated by the plant operating staff and preventive action taken to protect the fish. However, there were repeated incidents where the pH fluctuations were neither anticipated nor controlled and these incidents led to severe distress and/or death of the fish.

Once the lethality of these pH fluctuations was fully appreciated the company made several attempts at modifying the pH control equipment to reduce the amplitude of the oscillations. These attempts had little effect as indicated by the events of November 27, when the remaining fish at this station were killed by a pH of 12.5.

The fish from station 5 showed two distinct types of tainting. One of these was of an oily nature and was noted after 23-days exposure at this station. The other type of taint was similar to a reduced hydrocarbon which smelled, in the raw fish, much like styrene. This second taint was noted after 11-days exposure.

CASE STUDY II

The refinery used in this project was capable of

processing 35,000 barrels of crude oil per day. The oily process waste water, approximately 400 IGPM, is passed in turn through two A.P.I. separators and then into equalizing basins. From the equalizing basins the effluent goes through a flocculation tank and primary clarifier and then through an activated sludge system. Following secondary clarification the effluent is subjected to ozonation and discharge to a holding basin where any storm water and surface runoff is added. The mixture of treated waste and storm water is then discharged.

METHODS

In order to monitor the effects of the untreated and treated waste on fish a mobile laboratory was installed for the duration of the study. This laboratory contained two proportional diluters as well as equipment for controlling the temperature of both the dilution water and the toxic feed stocks.

The diluters were set up to deliver raw waste concentrations of 0%. 0.5% 2%. 8% and 12% at the rate of 0.5-litres every 75 seconds. The treated waste was delivered at the same rate but at concentrations of 0%, 5%, 10%, 25%, 50% and 100%. Two hundred and seventy-five fingerling rainbow trout, acclimated seven days to site-specific Lake Ontario water were anaesthetized, weighed and distributed randomly to each of eleven 50-litre aquaria. This gave a final count of 25 fish per tank.

The daily inspection included recording of mortality and temperature, dissolved oxygen and pH measurements on the fish tanks.

Each day the fish in each tank were allowed a maximum of 10 gms of fish food. This food was given very slowly over a period of at least several hours. During the experiment the fish were weighed after 27 days, 42 days and 48 days exposure.

Treated and untreated effluent and exposure tank contents were sampled for chemical analyses ten times in 48 days. These samplings included those instances where fish kills were noted.

RESULTS

None of the observed responses of the fish were attributable to aberrant temperature, pH or dissolved oxygen levels.

Chemical Analysis - Raw Waste

Table 5 contains the results of chemical analyses performed on both the undiluted, untreated waste and each of the experimental tanks. The chloride values shown with an asterisk are the calculated percentage fractions taken from the 100% untreated waste. The chloride values without the asterisk are actual mean values measured on the contents of the tanks. The fish mortality noted in the 8% waste concentration was most likely caused by 0.78 ppm sulphide.

Chemical Analysis - Treated Waste

Table 6 contains the results of chemical analyses performed on both the experimental tanks and the undiluted, treated waste. The chloride values shown with an asterisk are the calculated percentage fractions taken from the 100% undiluted waste. The chloride values shown without an asterisk are the mean values measured on the contents of the tanks.

Toxicity - Raw Waste

Preliminary, acute toxicity testing using fathead minnows (Pimephales promelas, Rafinesque) showed that the untreated waste had a 48-hour TLm of 24% in a static bioassay. Using a constant flow bioassay and rainbow trout (Salmo gairdneri, Richardson) waste from the same source had a 48-hour TLm of 7%. At 2% there was a gradual attrition of the fish down to about 72% survival after 28 days following which no mortality was observed. No mortality was observed in the 0.5% v/v waste.

Toxicity - Treated Waste

Preliminary acute toxicity testing using fathead minnows (Pimephales promelas, Rafinesque) showed that the treated waste was not lethal in 96 hours at 100%. Using a constant flow continuous sample bioassay and rainbow trout, (Salmo gairdneri, Richardson) waste from the same source had a 96-hour TLm of 93% and a 192-hour (8 days) TLm of 39%. In addition, there was 100% mortality after 14 days at 50%, and 100% mortality after 20 days at 25%, and 60% mortality after 48 days at 10%. Upon closer inspection the mortality pattern is not one of a gradual response of the fish to a uniform toxicant concentration but rather a response to slugs of various toxicants present in the waste water feed stock.

Table 7 shows the results of certain chemical analyses performed on fish tanks at the time of a fish kill and on the undiluted, treated waste feed stock. Also shown is the average concentration of the same parameters measured in these fish tanks. These data indicate that at 50% and 100% concentrations ammonia and/or cyanide is the most likely toxicant. In the 10% and 25% concentrations cyanide is likely the lethal chemical. However, in the 10% concentration the 100% undiluted feed stock supplying that concentration shows elevated levels of ammonia and chloride which would suggest a general, slug discharge from the refinery. Such a discharge is likely to contain many other toxicants such as branched hydrocarbons, complex aromatic hydrocarbons, sulphur and nitrogen compounds.

Table 5: Chemical composition of Raw Waste Exposure Tanks

Parameter	Concentration					
	Control	0.5%	2%	8%	12%	100%
Phenol µg/l	3	63	195	691	3346	25,700
$S^{=}$ mg/l	0.1	0.1	0.3	0.78	2.7	187
HCN mg/l	0.01	0.01	0.01	0.05	0.03	0.18
E.E. mg/l**	1	1	1	4	3	12
B.O.D. mg/l	2.6	3.4	2.7	3.5	5.7	175
C.O.D. mg/l	30	30	30	30	30	350
Total Kjeldahl mg/l	1.2	1.3	1.4	2.7	4	49
NH_3 mg/l	0.18	0.2	0.5	1.7	2.3	41
NO_2 mg/l	0.03	0.03	0.03	0.09	0.05	0.12
NO_3 mg/l	0.3	0.3	0.3	0.3	0.3	0.3
Temp ^{o}C	14.0	14.3	14.1	13.8	13.6	
pH	7.5	7.6	7.7	7.9	8.0	9.4
D.O. mg/l	8.8	8.2	8.2	7.3	6.9	
Cl^{-} mg/l	32	33	37	57	65	374
		35*	39*	62*	77*	

**Ether extractable, non-volatile oil.

Table 6: Chemical Composition of Treated Waste Exposure Tanks

Parameter		Concentration						
		Control	5%	10%	25%	50%	100%	Treated Waste
Phenol	µg/l	3	5	7	9	14	18	20
$S^{=}$	mg/l	<0.1	<0.1	< .1	< .1	< .1	< .1	< 0.1
HCN	mg/l	<0.01	0.02	0.05	0.09	0.15	0.20	0.43
E.E.**	mg/l	1	1	1	1	3	3	3
BOD	mg/l	2.6	8.4	5.6	6	6.3	10.6	9.3
COD	mg/l	<30	<30	<30	<30	40	55	80
Total Kjeldahl	mg/l	1.2	3.4	5.0	10.2	20	35	45
NH_3	mg/l	0.18	1.6	3.0	9	18	33	39
NO_2	mg/l	0.03	0.13	0.16	0.18	0.26	0.63	0.51
NO_3	mg/l	0.3	0.4	0.4	0.4	0.4	0.64	0.57
Temp.	^{o}C	14.3	14.5	14.6	14.5	14.7	14.9	
pH		7.6	7.5	7.6	7.7	7.7	7.7	7.7
DO	mg/l	8.8	7.8	8.5	8.9	8.7	8.3	
Cl^{-}	mg/l	32	51	65	133	236	433	435
			54*	75*	141*	249*		

**Ether extractable, non-volatile oils.

Table 7: Concentration of Specified Parameter (mg/l)

	Measured conc. in tank during mortality	Mean Conc.	Mean Conc. 100%	Conc. in 100% Waste during mortality
100%				
NH_4	43	39	39	43
HCN	0.07	0.43	0.43	.07
Cl^-	440	435	435	400
50%				
NH_4	20	18	39	41
HCN	0.05	0.15	0.43	0.11
Cl^-	220	236	435	440
25%				
NH_4	10	9	39	42
HCN	0.2	0.09	0.43	.7
Cl^-	128	133	435	454
10%				
NH_4	6	5	39	56
HCN	.1	0.05	0.43	1.0
Cl^-	47	65	435	471

Growth - Raw Waste

There was an evident anomaly in the growth of fish exposed to the raw waste. The fish exposed to the 0.5% v/w raw waste grew considerably faster than the control fish, while the fish exposed to the 2% raw waste grew slower than the control fish.

- Treated Waste

After exposure of the trout for forty-eight days to the treated waste the following percentage increases in weight were observed:

Conc. Waste	% Increase over starting wgt.
Control fish	426%
5%	213%
10%	180%
25% (extrapolated from a 20-day exposure period)	41%
50%	0 (total mortality in 14 days)

DISCUSSION

Raw Waste

The observed anomaly in growth may be the result of several factors. Vibration from nearby pumps controlling the pre-dilution of the raw waste may have affected the fish. Fumes emanating from the diluted raw waste may also have had an effect on the fish. The fact remains that the fish exposed to 0.5% raw waste grew more quickly than the control fish while those exposed to 2% raw waste grew more slowly than the control fish and fish exposed to 8% raw waste could not survive more than a few days. The observed toxicity was most likely the result of sulphides. Since the waste had not been oxidized at this point dissolved hydrocarbons and complex sulphur and nitrogen compounds ought to be suspected as well. The presence of some hydrocarbons was suggested by the measurement of 4 mg/l ether extractable oil found in the 8% waste.

Throughout the duration of this program only one major slug was detected in the raw waste. In this slug the chloride concentration reached 762 ppm ($\bar{x}$ of 364) and ammonia reached 70 ppm ($\bar{x}$ of 41) This slug caused some mortality in the 2% raw waste tank.

Treated Waste

The results of this experiment show that the treated refinery effluent was capable of inhibiting the growth of fish even at low concentrations. Also, the waste was lethal to fish at 10% concentration. The data in Table 6 suggest that fish exposed to high

concentrations of treated waste were probably killed by ammonia. When the waste had been diluted ammonia was probably no longer acutely toxic but rather slugs of cyanide were the most likely lethal agents.

Following the completion of the biomonitoring program at this oil refinery changes in in-plant effluent handling procedures were completed and resulted in a decrease of approximately 50% in the effluent ammonia concentration.

There appears to be a fundamental difference in the manner in which the two industries handle their waste water. The older petrochemical plant relies heavily on operator and in-plant controls that were not part of the original design and construction. Less emphasis is placed on external waste treatment. The newer oil refinery on the other hand relies mainly on external waste treatment and to a lesser degree on operator and in-plant controls to maintain effluent quality. The net result of these differences is that the petrochemical plant was better able to trace effluent irregularities to the source. This tracing was aided by having separated waste outfalls each draining one or more production units.

In the oil refinery, tracing effluent irregularities to source was more difficult because of the mixing of all the waste sewers and the reduced emphasis on in-plant control.

The pattern that emerges from studying the waste waters from these two plants is that the various parameters have a mean value around which they fluctuate with a certain frequency and amplitude. Both of these wave characteristics are going to control the toxicity of the waste.

Perhaps the single biggest advantage of biomonitoring over chemical monitoring is that the fish's response will be to all contaminants present in the waste and such responses will be tangible and observable, on a real time basis. When effluent irregularities are observed, sampling and analysis of the fish tank contents is a relatively simple matter. Biomonitoring gives both management and staff an opportunity to observe the cumulative benefits of their waste management program. When the fish are no longer killed by repeated slug discharges and when they can survive for extended periods in the waste water, major improvements have been achieved.

Another advantage of biomonitoring is that problems such as decomposition, alteration of chemical composition or loss of volatile components can be largely circumvented by <u>in situ</u> biomonitoring of the effluents.

The major disadvantage of a biomonitoring program is one of set-up time which can be as much as a month or more depending on the complexity of the experimental design. Depending on the complexity of the problem, the cost of a biomonitoring project can be as little as a few hundred dollars or as much as $10,000 plus. In planning a

biomonitoring project, adequate provision must be made to provide sufficient man hours and equipment to maintain complete control of the experiment. The control of a biomonitoring project may involve periodic acute toxicity measurements on the waste. Chemical analysis of the effluent for known or suspected toxicants is essential. It may not be necessary but the possibility of 24-hour surveillance, seven days per week should be considered. The chief difference with biomonitoring is that it involves a different type of technology.

The waste concentration ranges evaluated in case studies I and II went from 5% to 100%. The continuous flow toxicity data collected from these studies show that there exists a high probability of adverse effects to fish inhabiting the receiving water in the vicinity of the outfalls. The data show that dilutions considerably greater than those used in the experiments would be required before the effluent, as discharged, could be considered as harmless with respect to acute toxicity, growth and flavor impairment. Controlling acute toxicity through increased in-plant dilution is not an acceptable alternative to effective waste treatment and control. It has been recognized that in the mixing zone around the point of discharge there may be less than optimum water quality conditions with respect to sub-acute biological responses. If the zone of dilution is considered as that amount of receiving water necessary to dilute the waste to a reasonably uniform concentration, then there should be no adverse effects on fish outside this zone and such levels will be acceptable providing they meet existing water quality guidelines and criteria for all uses.

A biomonitoring program can be set up such that the dilution water is that water taken immediately upstream of the discharge, and the experimental concentrations can be set up to represent the undiluted waste, the waste during dilution, the waste at the margin of the zone of dilution and the waste beyond the zone of dilution. Fish exposed to the last concentration should show no adverse effects from the waste.

Along a river each water user will have no control over the quality of the water coming to it. Thus, it becomes the responsibility of the regulatory agency to ensure that every water user receives the highest possible quality water and in turn discharges the highest possible quality effluent which will be subsequently reused downstream.

Biomonitoring is a tool which can be used to assess the suitability of effluents for aquatic life and to contrast these to receiving water conditions above the point of discharge, at the margin of the zone of dilution and beyond the zone of dilution.

The maintenance of a successful effluent biomonitoring program has certain similarities to the maintenance of a successful safety program. Just as a safety program demands considerable dedication and attention from both management and staff, so does a biomonitoring program. Indeed, the death of the fish in the exposure tanks might be looked upon as the death of a fellow worker.

CONCLUSIONS

1) Grab samples of the final effluents from an oil refinery and a petrochemical plant were non-toxic to fathead minnows when tested for 96-hours at 100%.

2) Using *in situ* biomonitoring techniques both plants were shown to be discharging wastes that were subject to considerable fluctuation in quality and were frequently lethal.

3) When the wastes from both situations were diluted to non-lethal concentrations inhibition of fish growth was observed.

4) Using oil refinery effluent inhibition of growth was proportional to concentration.

5) Biomonitoring has the advantage of providing instant, easily interpreted data.

6) The real value of biomonitoring has yet to be realized. It is a technique which can be used to supplement chemical data to better understand the biological effects of industrial effluents and by relating these effects to specific on-site conditions will enable realistic predictions of localized impact on the aquatic biota.

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J. B. Greenshields

DEVELOPMENT OF A REFINERY WASTE WATER TREATING SYSTEM

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1. GENERAL BACKGROUND INFORMATION

Sun Oil Company Limited has always been aware that oil refineries can be responsible to a certain extent for emissions which can cause a deterioration of the environment, and that it was, therefore, obligated to provide protection as required to alleviate the deterioration. Consequently, the Company's involvement in preserving the environment did not begin during the more recent period of general public awareness and concern, but rather was part of the initial design objectives during the refinery construction in 1953. For successful operation a Company must not only meet the test of competition in serving the needs of its customers but must also exercise care so that the conduct of its business does not despoil the land, air or water. It has been and is the policy of Sun Oil Company not only to comply with all appropriate environmental regulations, but also to adopt every reasonable procedure which

will afford protection and conservation of our air and water resources. Each employee is aware of this policy and is encouraged to assist in attaining the Company's objectives by exercising due care and precaution to prevent and control air and water pollution in the performance of all duties.

The upgrading of refinery effluents over the past twenty years has been an ongoing programme which we plan to continue in the future.

This presentation will cover the various stages of development of the waste water treatment and handling facilities at the Sarnia Refinery of Sun Oil Company from the time of the refinery construction in 1953 until the most recent addition of facilities designed by M. M. Dillon Limited in 1972, and put into operation in early 1973.

For general information purposes we refer to a simplified flowsheet of our Sarnia Refinery.

2. REFINERY WATER POLLUTION ABATEMENT SYSTEMS (1953 TO 1971)

2.1 General

The design of the Sarnia Refinery in 1952 presented a unique opportunity to construct pollution abatement facilities as an integral part of the plant and to provide for the expansion of waste treatment equipment as needs dictated.

The Sarnia Refinery was orginally designed to process 15,000 Bbls/day of crude and over the ensuing years this capacity has increased to about 39,000 Bbls/day by equipment modification and alteration. A major capacity expansion, currently being constructed, will result in a total refinery crude capacity of about 80,000 Bbls/day when completed in 1974.

2.2 Segregated Collection Systems

The original installation which was placed on stream in 1953 included an extensive segregated sewer system. This installation included separate systems for:

1) Process waste water which was defined as all phenolic bearing waste water including some which also contained oil.

2) Contaminated storm drainage from all process areas and oily contaminated waste water (non-phenolic) from blowdowns, etc.

3) Once through cooling water for shell and tube heat exchangers.

4) Sanitary Sewers - This system included run-off from the septic tanks servicing the office and other buildings. The main sanitary effluent is chlorinated before joining the main refinery water effluent stream.

An additional segregation system was installed in 1955 to separate high sulphide-bearing waters from the process waste water system. This system is discussed in detail later.

2.3 Gravity Separators

The first three systems, i.e. process waste water, contaminated storm drainage and oily contaminated waste water, and once through cooling water were provided with individual oil-water separators of A.P.I. design for removal of oil and settleable solids. These separators were equipped with mechanical collectors.

The oil skimmed at the A.P.I. oil-water separators is pumped to slop oil tanks before transfer to refinery feed tanks for re-run. Settled solids are transferred to desludging pits for further separation.

2.4 Process Wastes Treatment System

The system was designed with a capacity of 500 GPM to treat the main oxygen consuming contaminants in the refinery. These contaminants, mainly phenolic in nature, originate with the catalytic cracker and are dissolved in the water in the fractionator overhead accumulators. Other sources of the contaminants are crude desalter water, flare knock out drum water and pump gland leakage. Boiler blowdown water is routed to this collection system in order to take advantage of the phosphate content, which is added as boiler feed water treatment, in the secondary treatment section.

In order to reduce the phenolic and other oxygen consuming contaminants, a biological oxidation activated sludge system was designed as a secondary treatment process. This in the early 1950's was a pioneering achievement in the petro-chemical industry.

Since the process was relatively untried for the treatment of refinery waste water (being the second unit among all Canadian refineries), design parameters were based on information supplied by Dow Chemical Company and Imperial Oil Company Limited. No other process data for design of the unit was available.

The method selected for aeration of the mixed liquor was a diffused air system in which feed water, recycle water and air were injected through 40 Penberthy ejectors at the bottom of a partially concrete lined earthen pond. The liquid depth in the pond was set at 10 feet. The air was supplied from a 40 HP positive displacement low pressure blower. This installation was placed on stream in 1953 with average daily loadings of around 100 lbs. of phenol. There were, however, no provisions for treatment of feed water prior to charging to the biological unit and excessive amounts of sulphides and fluctuations in pH caused problems with phenol removal. From the initial operations, the sulphides were found to be toxic to the activated sludge and hence a separate collection system for sulphide-bearing waters was installed. The water collected in this system was treated through a flue gas sulphide stripping tower prior to feeding to the biological unit.

Originally one half of the A.P.I. oil-water separators in oily contaminated storm water service was used as a settling and sludge return facility for the biological unit. However, in 1956 a circular clarifier with two sludge return pumps were added as an alternative method of sludge settling. A simplified flow sheet of these initial waste water treatment facilities is shown in Figure I.

For eight years this waste water treatment operated satisfactorily. Variations in flow and characteristics of the feed water were found to be important factors affecting the phenol reduction through the facility.

2.5 Disposal Well

The refinery had been continually increasing throughput by modification and expansion during the 'fifties'. At crude rates of about 25,000 barrels per day, indications were that the waste water treatment system as originally designed had physical limitations for phenol removal.

A complete review and study of the expanded requirements and the economics of alternatives indicated that the installation of a deep disposal well in the easily accessible Detroit Sands formation with subsequent shutdown of the biological unit would best serve our purpose.

After selecting a well site within the refinery, a deep well was drilled to the Detroit Sands formation. Auxiliary equipments such as a well injection pump and surge tank were acquired, and the disposal of high phenolic water streams to the well was started in 1965. The biological unit was kept on stream treating low phenolic, low H_2S streams and the H_2S stripper was shutdown. This new combination of disposal of high phenolic streams and treatment of low phenolic streams operated well and the quality and consistency of the refinery effluent water to the St. Clair River improved considerably. Typically the raw waste dropped from more than 50 ppm phenolics to less than 5 ppm; the clarifier effluent dropped to less than 1 ppm from approximately 2.5 ppm and the total refinery effluent dropped to less than 50 ppb phenolics from a previous level of about 250 ppb.

Disposal wells in the Detroit Sands formation although very dependable, had histories indicating the possibility that at high rates plugging of the formation could occur. In order to reduce the flow rate, equipment was modified to permit the use of sour water as crude desalting water. Laboratory tests indicated that a 60% reduction of phenol and H_2S content could be obtained in the water which could then be routed through the H_2S stripper to the biological unit. Figure II illustrates these additions to the waste water treatment facilities. However, this procedure is not used on a regular basis at present.

2.6 Strong Caustic Wastes System

As mentioned previously phenolic wastes in oil refineries originate mainly in catalytic cracking operations and steam condensates which are in contact with these catalytic products extract the phenolic materials. Another integral part of refinery operations is the so-called sweetening of gasoline and other distillates prior to sale. The sweetening process used at our Sarnia Refinery converts highly odorous mercaptans in refinery products to non-odorous compounds by contact with a NaOH solution, in the case of our refinery. Unfortunately, NaOH solution has a great affinity for phenolic material and spent caustic from this sweetening process contains large quantities which it extracted from the products. The refinery sold this spent caustic solution to a chemical company who extracted

the phenolics (which were up to 30% by weight). However, leaking pumps and transfer lines were continuous sources of contamination of the refinery effluent stream as was an accumulation of trace amounts carried over with the gasoline streams into storage tanks and subsequently into bottoms water. To prevent this contamination by leakage, all drainage from caustic treating areas was routed to the H_2S sump which was tied into the deep well disposal system and the treaters were modified to prevent carry-over with product and accumulation in storage tanks. These modifications are illustrated in Figure III.

2.7 Impounding Basin

During the period 1960-1970 the refinery crude throughput was increasing steadily. This increase in production required continually increasing shipments of product from the refinery by ship and a corresponding increase in ballast water discharging which required treatment through our oil separation system prior to discharge to the river.

While ships were discharging their water ballast through our system, an increase in the oil content of the refinery effluent was noticed. At times our permissible criteria of 15 ppm was exceeded. To overcome this problem and provide additional safeguards in case of serious oil spills within the refinery such as storage tank rupture, it was decided to install a 2 million gallon earthen retention basin equipped with oil skimming facilities which would also prevent high oil content in the refinery effluent during ballast discharging. This retention basin which we call impounding basin was installed in 1970 and the streams from the oily contaminated water A.P.I. separator and the biological clarifier which had been routed directly to the refinery effluent stream were diverted through this basin prior to discharge. This modification is shown in Figure IV.

At our normal flow rates from these streams the retention time was about 1 - 1-1/2 days and the improvement in the oil content of the water being discharged to the river was very significant. However, the oil which started to accumulate on the surface of this basin indicated that the efficiency of the A.P.I. separators to remove oil was not as high as the oil content data of our refinery effluent indicated.

2.8 Secondary Oil Separator

The need for additional treating facilities to remove the oil from water after the A.P.I. separator was investigated, and as a result of the studies, it was decided to install some additional oil removal equipment. Based upon documented operating performance, a Wemco froth flotation separator was selected for secondary removal of oil which passed through the primary A.P.I. separator handling the contaminated waste water.

The unit was commissioned in December 1970. It has a 3,000 GPM capacity in four separate compartments each having an electrically driven rotor to inject air under the surface and float the oil in the form of a froth to the surface where it is skimmed off. With the aid of chemical flocculents, i.e. polyelectrolytes, oil removals of between 70% - 90% and suspended solids removal of about 60% have been achieved. The type of chemical flocculent used and the rate of application appear to be important factors in the efficiency of this method of oil removal from waste waters. This addition to the treatment facilities is shown in Figure V.

3. REFINERY WATER POLLUTION ABATEMENT SYSTEMS (1971 TO PRESENT)

3.1 General

The disposal of high phenolic wastes by deep well injection had been both efficient and economical since its inception. However, due to the possibility of subsurface strata fracture and consequent seepage into nearby oil producing wells and/or irrigation water wells the Provincial Government issued a directive in 1971 stating their intention of regulating deep well disposal of waste water and encouraging the use of surface treatment of such wastes by 1973. At this time it was expected that difficult-to-treat wastes, such as caustic solution drainage from treaters, could still be injected to the disposal well after the regulations came into effect and segregation of our high phenolic caustic waste streams was initiated. An additional underground storage sump was constructed and all caustic drainage from treater areas was routed to this collection sump. This sump was tied into the deep well disposal system so that although there was segregation, disposal was still possible by injection to a deep well.

Our management decided that a new treatment system for all phenolic waste waters was required as soon as possible. After a review concerning the equipment requirement for surface treatment of all phenolic bearing refinery waste waters, the Consulting Engineering Company, M. M. Dillon Limited were retained to determine the requirements necessary to meet the environmental standards for refinery effluent waters and to perform studies and process design for a treatment system. These studies were to be conducted for the refinery as it existed and allowances were included for a proposed refinery expansion to 80,000 Bbls. crude throughput per day.

At the time of review of the refinery equipment requirements for surface treatment, our effluent being discharged to the St. Clair River was meeting the Ministry of the Environment and International Joint Commission guidelines. However, at times the allowable phenol concentration of 20 ppb was exceeded and if the disposal well was to be abandoned, this condition would worsen. Nevertheless, the impact of this in the river was not significant since river water did not show a phenolic content above 5 ppb from all sources in the Sarnia Industrial Complex.

Nonetheless, in view of the fact that phenol requirements for refinery effluent streams appeared to be increasingly stringent in the proposed Federal standards, a goal was established. This goal was to provide facilities which would treat all refinery waste streams by surface treatment to give an effluent of the same or better quality than had been achieved with deep well disposal in use.

3.2 Work Performed By Consultant

Our Consultant commenced work on this project during the summer of 1971. Scope of the work was as follows:

1) To review Sun Oil and Ministry of the Environment data on refinery effluent water.

2) To carry out flow measurement and an analysis program for the phenolic wastes.

3) To report on flows and composition of phenolic wastes and arrive at design figures for the present refinery throughput of 38,000 Bbls. per day and the expanded refinery throughput of 80,000 Bbls. per day.

4) To perform treatability studies on a raw waste water blended in accordance to the flow data obtained for all phenol bearing streams.

5) To translate the treatability data into a process design for an optimal treatment scheme.

6) To develop preliminary layout, construction planning and an order of magnitude estimate for capital and operating costs.

7) To submit a final report of work done, presenting all of the data, including a process design.

8) To preselect necessary equipment (in this case aeration equipment) to treat the wastes.

The work performed by the Consultants was broken down into three phases.

Phase I - To conduct an in-plant study.

Phase II - To perform treatability studies for determination of design criteria for full scale unit.

Phase III - To report on the results of these studies providing a process design as well as recommendations as to necessary equipment for full scale treatment facility.

Phase I (In-Plant Study)

This study consisted of a review and characterization of all waste water streams in the refinery. Flow measurements were taken over an average span with as many streams as possible flowing to the process sewer. Other streams were measured individually. A summary of flow data obtained is presented in Table I. This data was assembled from actual flow measurement data such as presented in Graph No. I.

Concurrent with the flow measurements, grab samples and 24 hour composite samples of the streams were obtained in order to ascertain concentrations for design purposes. Some typical analyses are shown in Table II.

Phase II (Treatability Studies)

In order to produce a refinery effluent containing 20 ppb of phenolics, it was calculated using the data obtained in Phase I that after treatment the waste water should have a phenolics concentration less than 200 ppb since the other components of the refinery effluent would effect a concentration dilution. Several processes were evaluated and activated carbon, reverse osmosis, and solvent extraction were discarded in favour of biological oxidation.

The following charcteristics for the processes evaluated were taken into account in this decision.

a) Activated Carbon Absorption

This process has been used for many years for removing dissolved impurities from waste water. However, its use has been mainly as a final polishing stage after some other form of treatment. It was not considered because:

1) The problems of charcoal regeneration would be considerable if used as a first stage treatment system.

2) A possibility existed that charcoal would be easily fouled with entrained oily material.

b) Reverse Osmosis

This process is successful in the removal of dissolved organic materials from waste water. However, it was not considered for this type of application for the following reasons:

1) The flow to be treated would require an extensive capital investment and would be a complex unit.

2) The membranes employed by the process are easily polarized by the presence of oil and would require an additional highly efficient oil removal pretreatment unit.

c) Solvent Extraction

This process has been carried out successfully, on laboratory scale, for removing phenolic compounds from waste water. It was not considered in this case due to the high capital and operating costs, which would be required for a full scale unit (e.g., a solvent recovery system).

d) Biological Oxidation

This process is now widely used for the treatment of petroleum and petro-chemical phenolic waste water. The refinery already had an operating biological unit with personnel experienced in its operation, and re-use of certain existing equipment would be possible. Since the economics of phenol removal by this process are also the most favourable, this process was chosen for a detailed study.

It was originally considered that conventional textbook lab bench tests could be used for determining the required process design parameters. This concept however had to be abandoned in favour of continuous flow equipment representing the completely mixed aeration system. Apparatus was constructed as shown in Figure VI.

This apparatus consisted of:

1) A stainless steel feed tank.

2) Metering pumps for the feed solution and biological sludge return to the aeration vessel.

3) A clarifier constructed from laboratory glassware.

4) A 14 litre capacity New Brunswick continuous reactor equipped with regulated and metered air supply, turbine mixers and automatic pH and temperature control.

5) An effluent collection bottle.

The reactor was operated at 10 litres capacity using acclimated sludge obtained from an operating refinery biological unit. The operating conditions were varied according to the objectives of the study for a period of 3 months to arrive at the following operating criteria for the desired phenolic concentration of less than 200 ppb in the effluent container.

1) M.L.S.S.

Optimum operation was achieved with a concentration of 2000 mg/L.

2) Ratio M.L.V.S.S. To M.L.S.S.

Conditioned sludge exhibited a ratio of 0.66.

3) Sludge Volume Index

This ratio of biological sludge volume to weight was consistently in the range of 85 to 100.

4) Recycle Ratio

This rate of biological sludge return to the aeration vessel was determined to be 25% of feed rate for optimum conditions.

5) pH Control

Operation was best at a pH of 7.

6) Temperature

Optimum conditions at 23 to 25°C (73 to 77°F).

A summary of these and other design parameters obtained from the continuous bench scale pilot plant studies is presented in Table III.

Phase III (Report And Recommendations)

The report from the Consulting Engineering Company for a biological plant which would allow the refinery to surface treat all waste water streams, discontinue deep well injection, and meet all the stated requirements for a final refinery effluent to the St. Clair River recommended the following:

1) Construction of a concrete aeration tank of 750,000 I.G. capacity.

2) Installation in this tank of 4 - 60 HP "Lightnin'" surface aerators with oxygen transfer efficiency rated at 3.58 lb.0_2/HP/hr.

3) Retention of the existing biological basin with existing aeration equipment and enlargement to provide a feed equalization system.

4) Retention of the existing biological clarifier with consideration for possible future addition.

5) Retention of all existing segregated sewer systems, piping and pumps with the exception of the sludge return pumps which might prove to be smaller than necessary for expanded refinery flows.

6) Installation of facilities for pH control and means to inject nutrients and artificial feed if required.

A diagrammatic presentation of flows, existing waste treatment facilities, and proposed addition facilities recommended by the Consulting Company for a total refinery waste treatment system is shown in Figure VII.

3.3 Construction And Operations Of Facilities

a) Biological Oxidation

Construction of the new facilities and modification of existing facilities, as recommended by the Consultant, were commenced in mid-1972 and completed, ready for use, by year end.

The new aeration basin was allowed to fill from the existing biological oxidation pit and the sludge was allowed to develop and acclimatize by slowly increasing the feed concentration.

b) Redesign Of H_2S Stripper

Concurrent to the above studies the sour water H_2S stripper was redesigned and relocated. The original stripper column was to be used, after packing with ceramic rashing rings. However, stripping was to be done by stream injection rather than flue gas which had previously been used. An overhead condenser with condensate knockout drum and feed-bottoms heat exchangers were provided.

The design parameters were to be 99% removal of H_2S and 95% removal of NH_3. A sulphuric acid injection system was provided to neutralize caustic feeds and also to remove ammonia as $(NH_4)_2SO_4$ in the stripper bottoms as necessary. A separate flash pot was provided to remove H_2S from desalter water and the overhead H_2S gas from the stripper is routed to the sulphur recovery plant rather than discharging to the atmosphere to comply with the requirements of the Air Management Branch of the Department of the Environment.

3.4 Performance Of Full Scale Facilities

Limited problems were experienced with corrosion in the H_2S stripper acid injection lines. However, these have been resolved and the equilibrium system now shows phenol reduction of from 50 - 100 ppm in the feed to 50 - 100 ppb in the aeration tank effluent which is well within the expectations. After introduction of phosphoric acid at the recommended dosage the sludge now exhibits very good settleability characteristics, is deep brown in color and exhibits the odor of fresh turned earth characteristic of active biological sludges. The data obtained on continuous operation of our biological system treating the total waste water flow including neutralized phenolic caustic wastes, is presented in Table IV. Comparison is made for predicted and actual performance vs. regulations in Table V.

3.5 Future Additions

As part of the 1973 refinery expansion, the following facilities will be added to the existing waste treatment facilities.

1) Cooling Tower for evaporative cooling of process water.

2) Flash pot for H_2S removal at the new crude desalter.

3) New pump, piping and valving to permit recycling of the impounding basin through the biological oxidation unit.

4. CONSTRUCTION AND OPERATING COSTS FOR REFINERY WASTE WATER TREATMENT

4.1 Capital Costs

The capital costs of the waste treatment facilities are presented in Table VI.

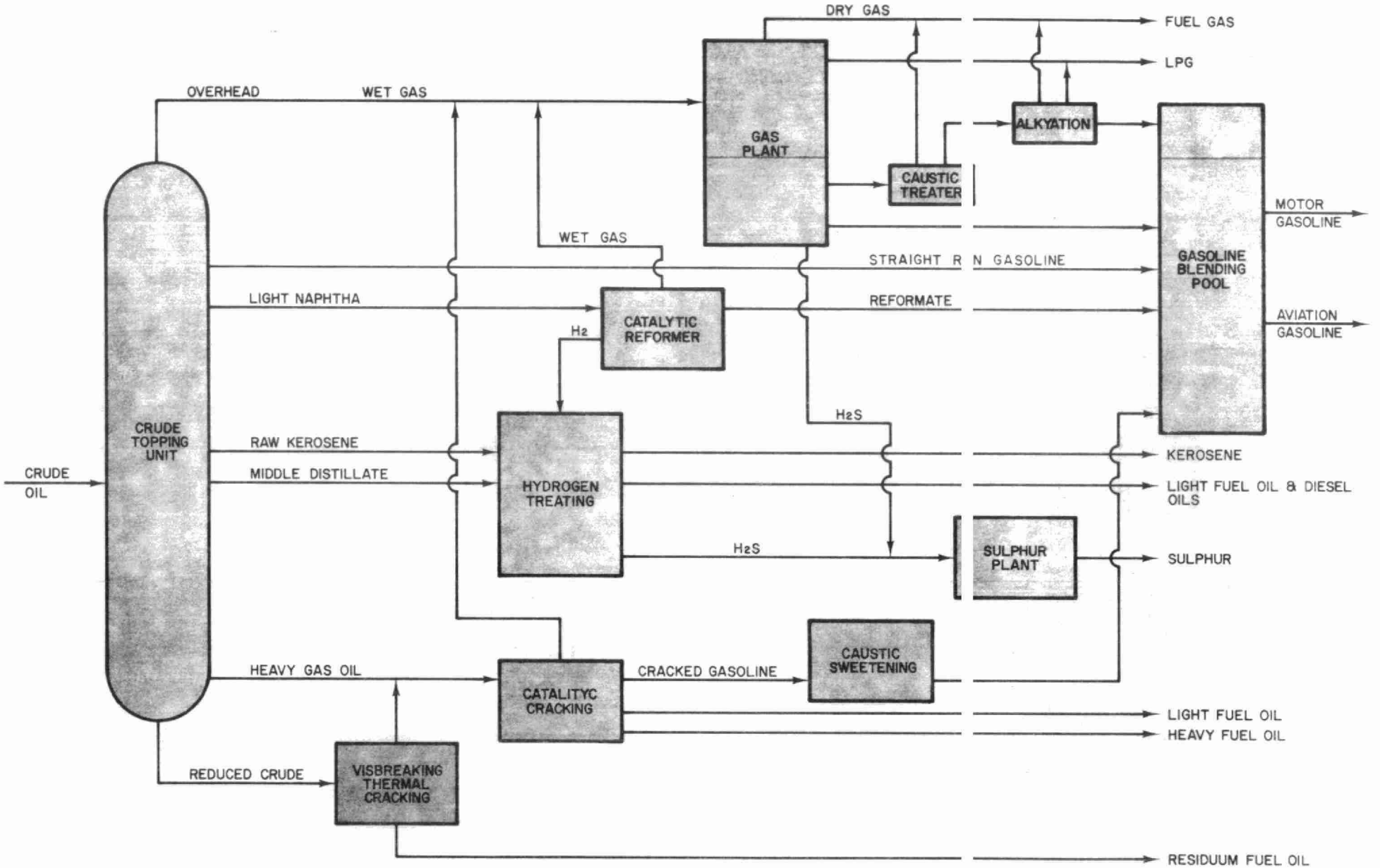
4.2 Operating And Costs

Data assembled to date indicated that costs for manpower, electricity, chemicals, insurance and supervision average $566 per day for the removal of 518 lb./day of phenolic compounds. This is approximately $1.09 per lb. removed.

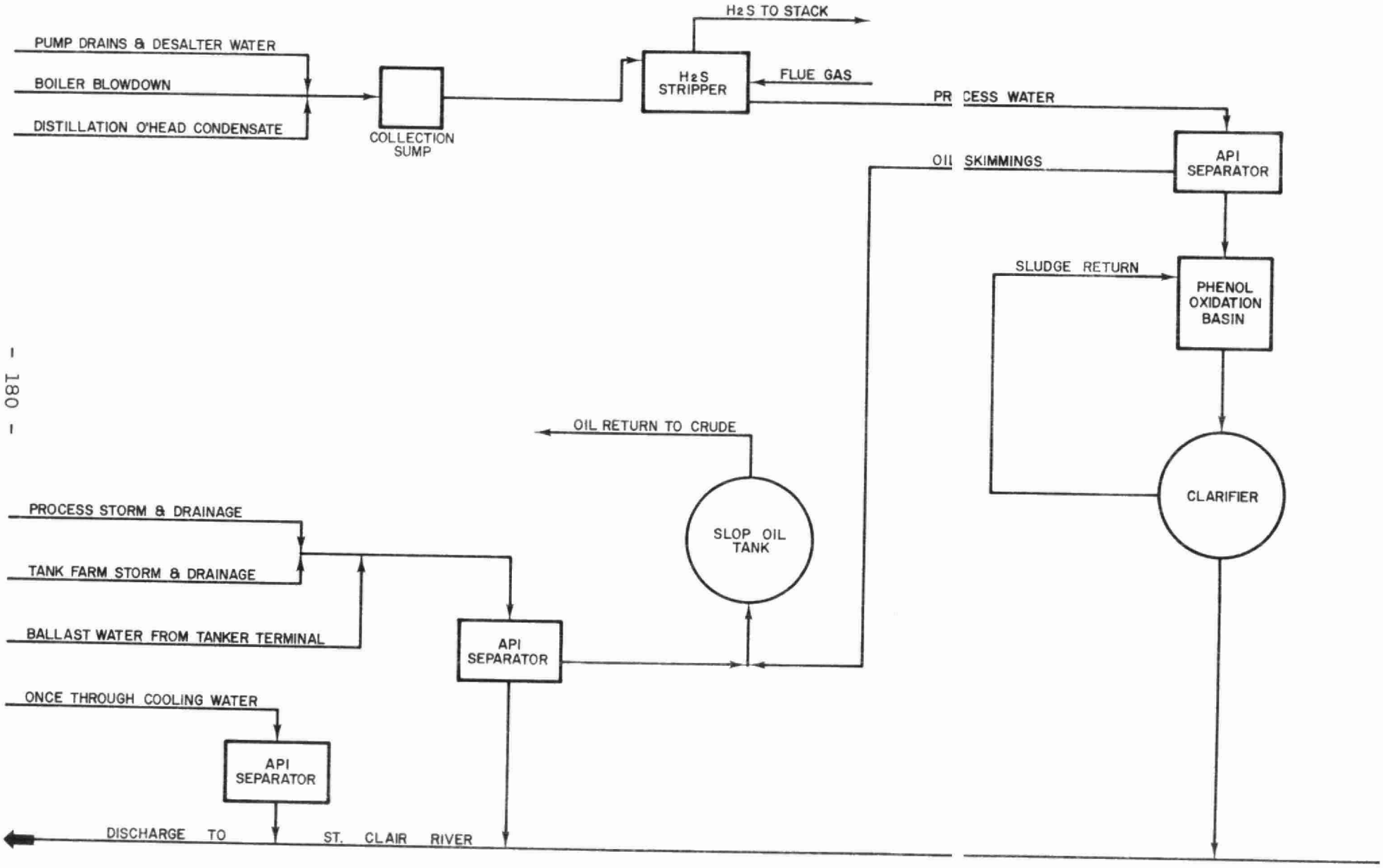
5. CONCLUDING REMARKS

This paper has presented the main areas of Sun Oil's involvement with the treatment of refinery waste water in its efforts to preserve the environment and comply with the regulations of the various Government agencies. It has been a continuous concern for the company to do all in its power to operate a clean refinery, unobtrusive to its neighbours. The development and enlargement of the waste water treatment facilities will undoubtedly continue over the next 20 years.

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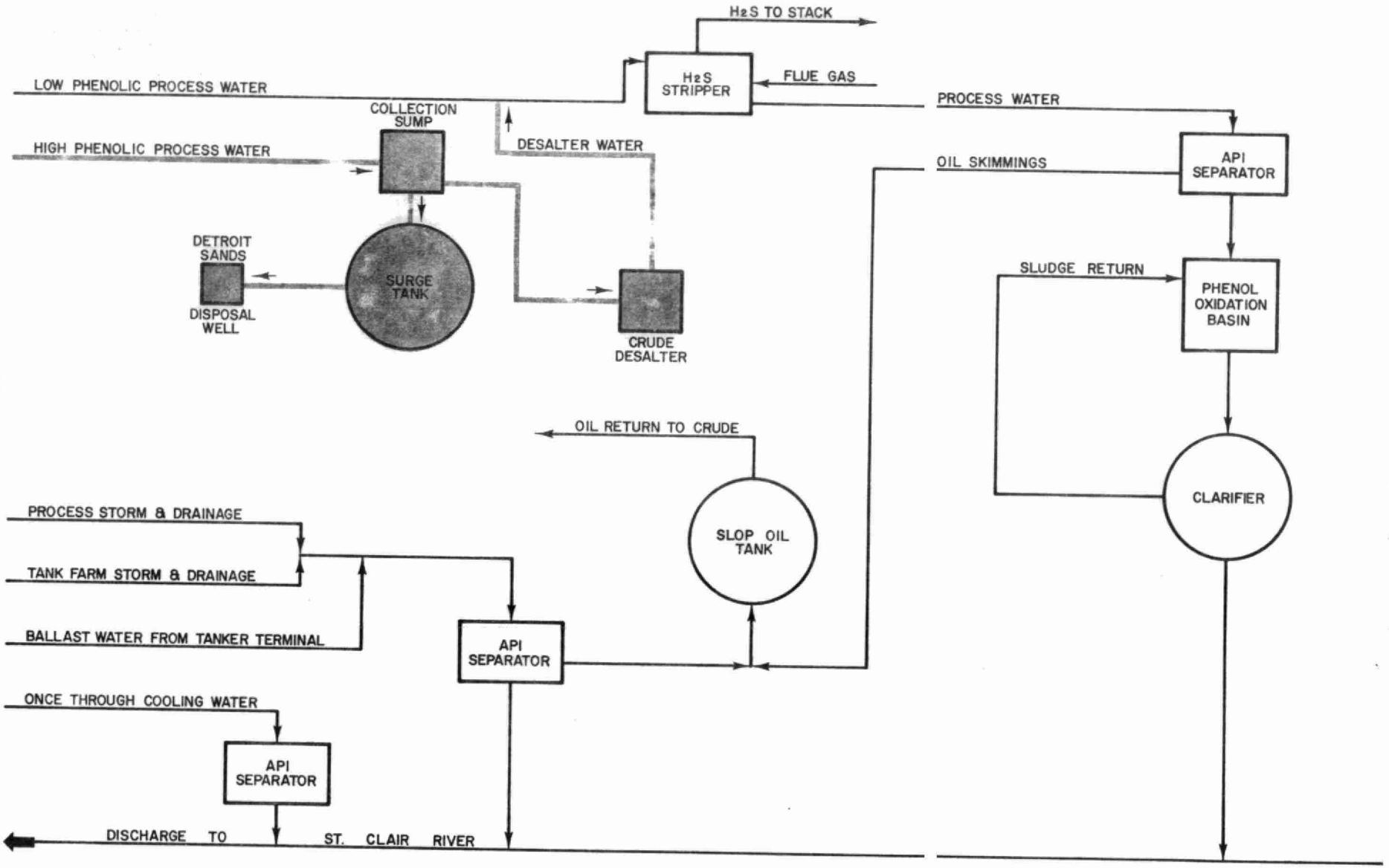


SIMPLIFIED FLOW SHEET FOR THE SARNIA REFINERY OF SUN OIL COMPANY



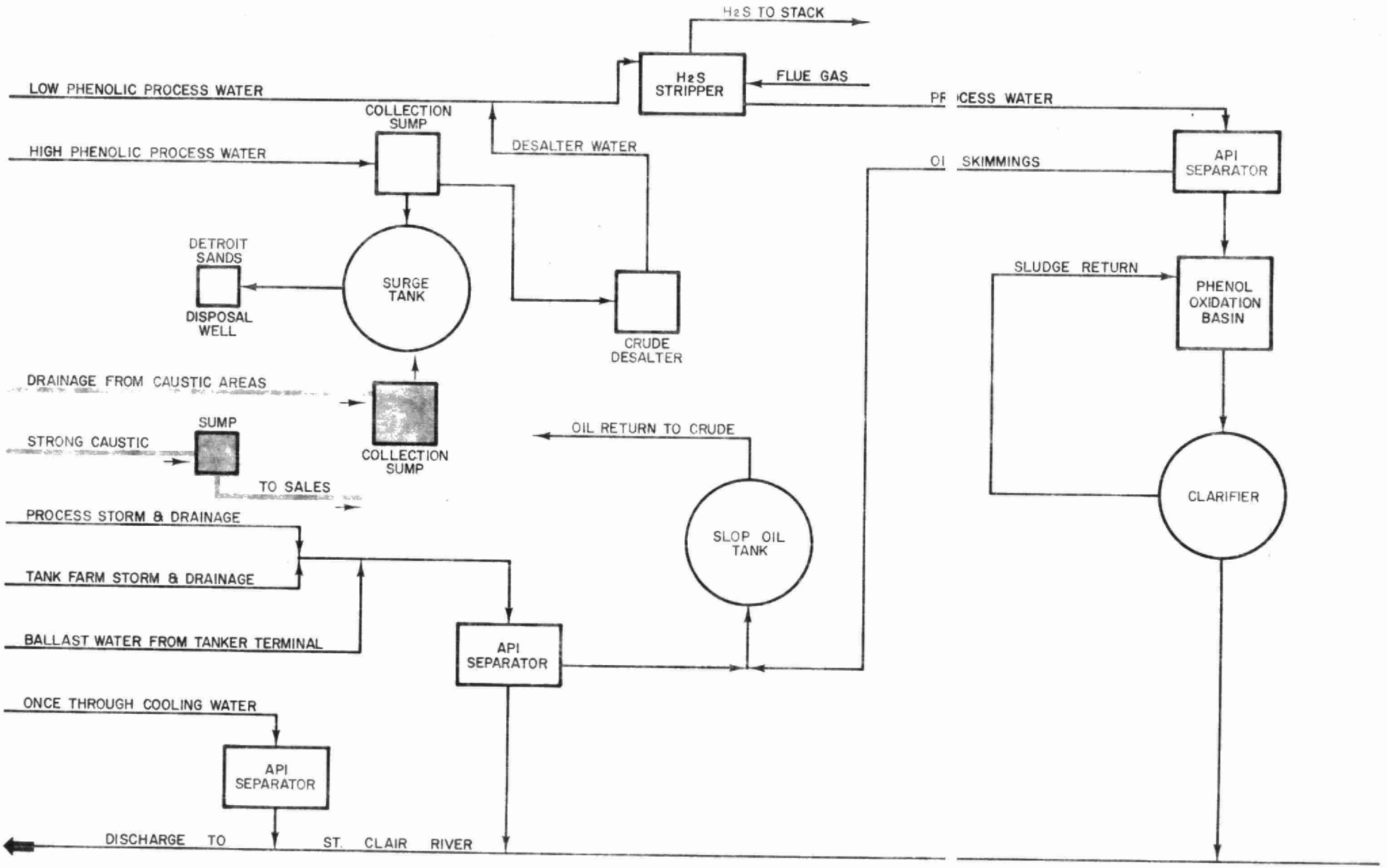
WASTE WATER TREATMENT FACILITIES AT SARNIA REFINERY IN 19.6

FIGURE 1



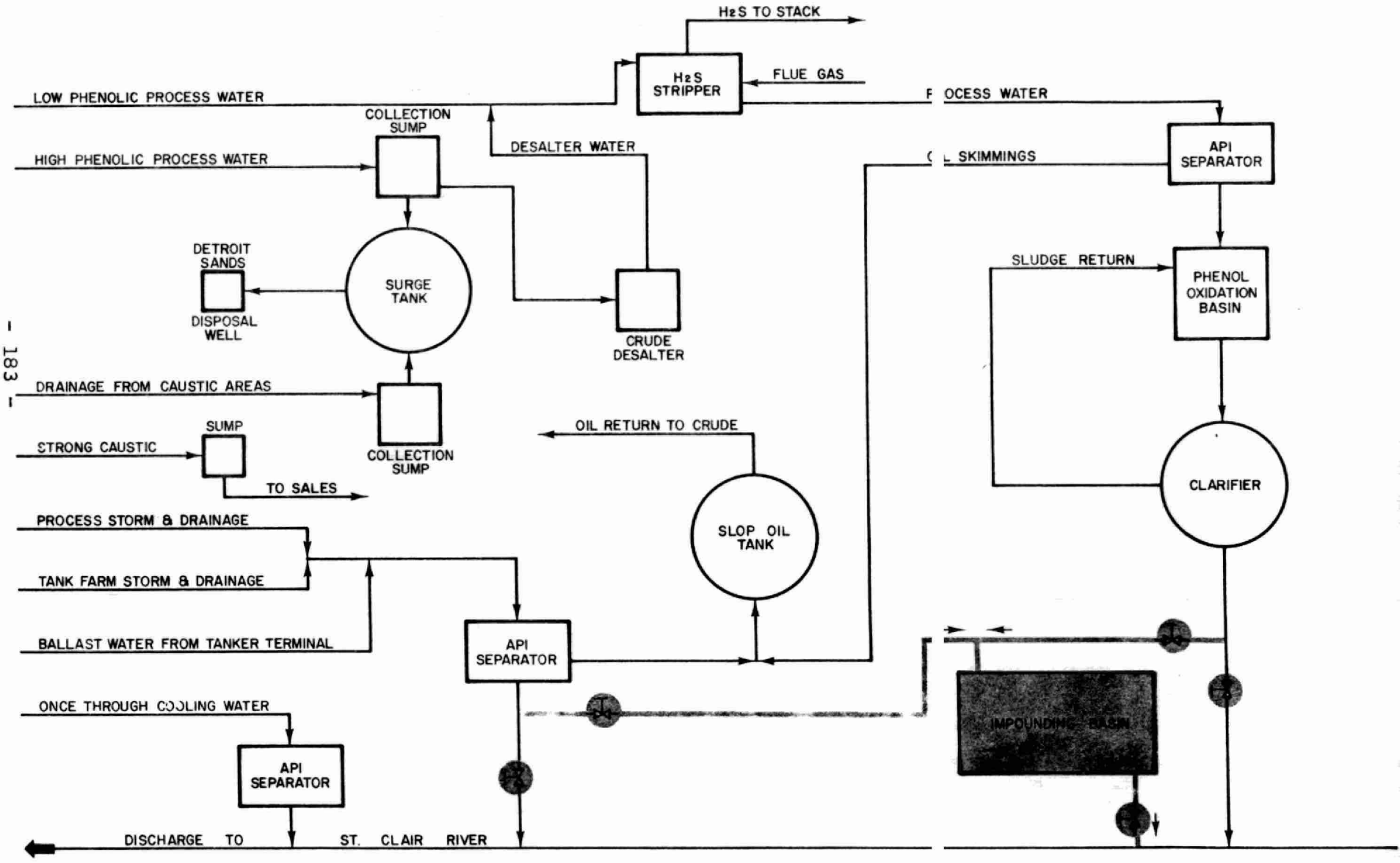
WASTE WATER TREATMENT FACILITIES AT SARNIA REFINERY IN '965

FIGURE II



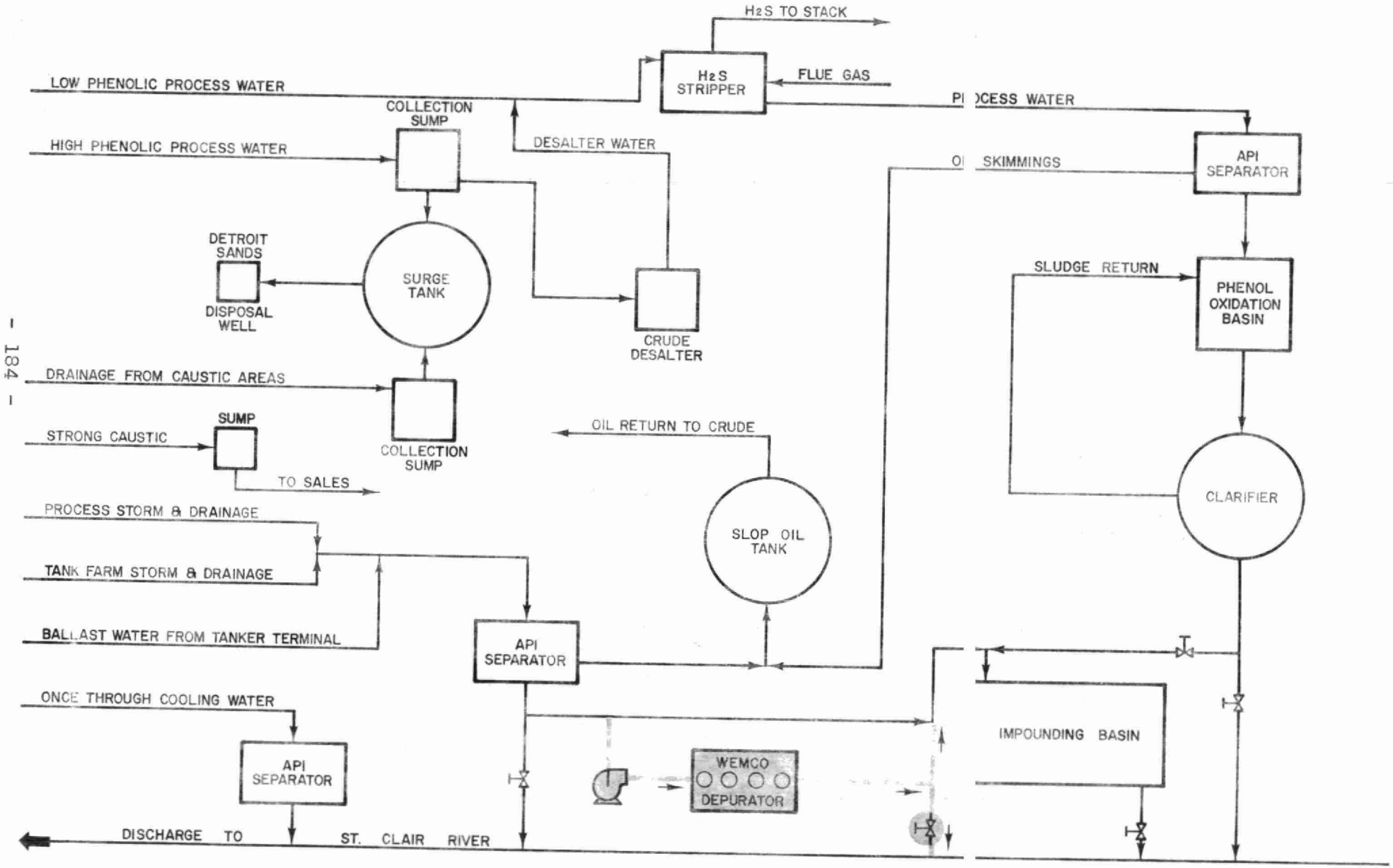
MODIFICATION OF GASOLINE TREATER

FIGURE III



ADDITION OF WASTE WATER RETENTION LAGOON [24 HOUR CAPACITY] IN 1970

FIGURE IV



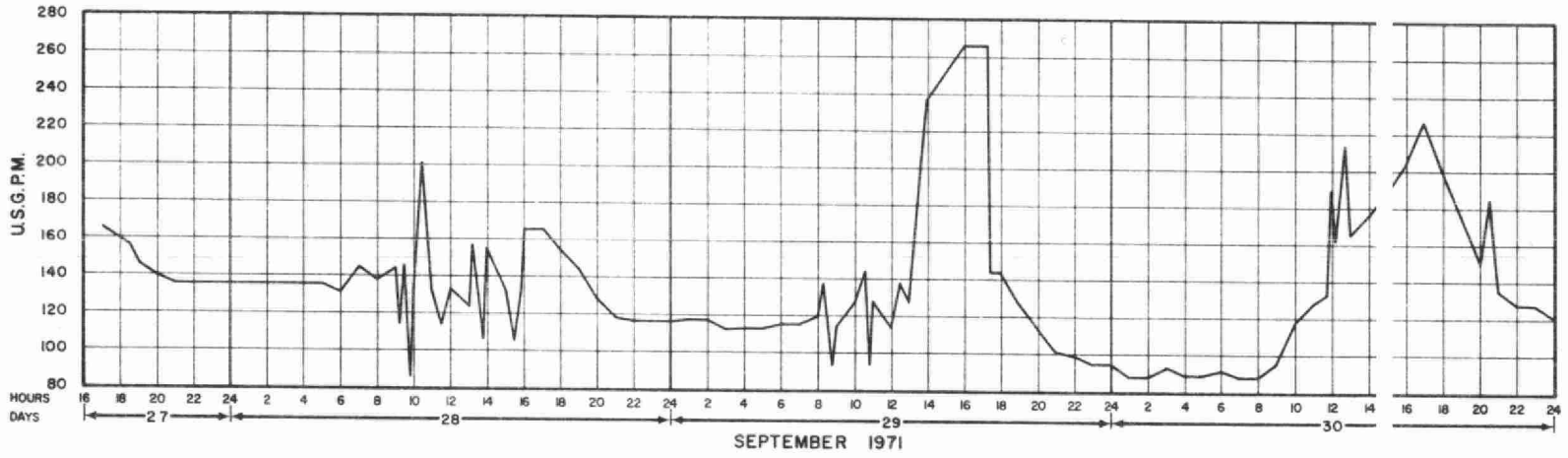
ADDITION OF WEMCO DEPURATOR TO REDUCE OIL EMMISIONS IN W ATER - 1971 FIGURE V

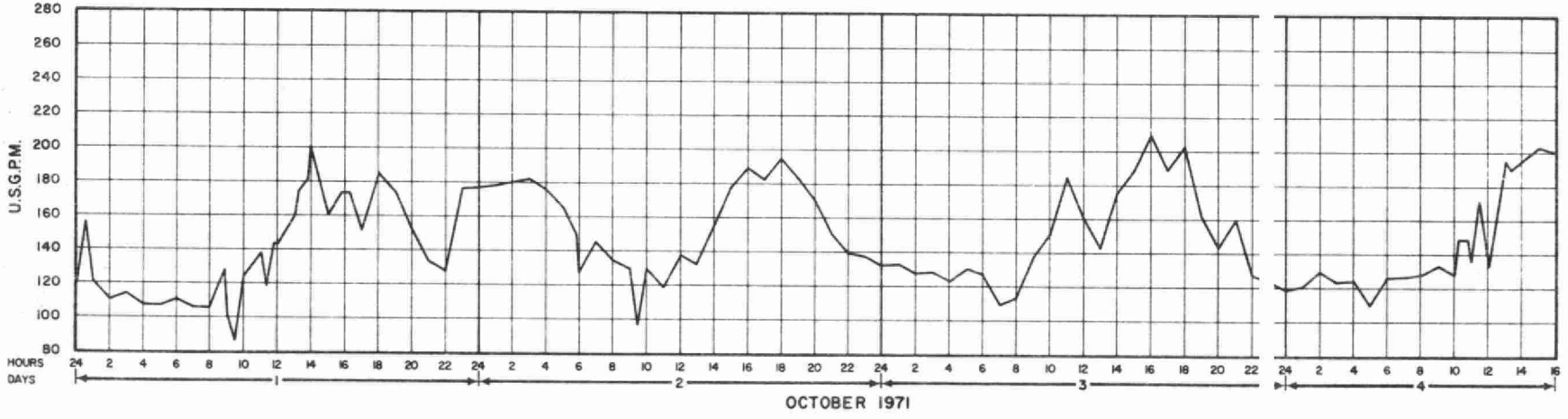
SOURCE	AVERAGE FLOW (USGPM)	
	PRESENT REFINERY	FUTURE REFINERY
PROCESS SEWER	74	74
CRUDE ACCUMULATOR	8	8
DESALTER	51	51
DILUTE CAUSTIC SUMP	10	10
H_2S SUMP	58	58
TANK 52 RERUN*	25	25
TANK BOTTOMS	22	22
FLARE SEAL DRUM	25	25
IMPOUNDING BASIN RECYCLE*	100	100
NEW DESALTER		51
NEW CRUDE ACCUMULATOR		8
TOTAL	373	432

* *INTERMITTENT*

SUMMARY OF FLOW DATA FROM IN PLANT STUDY

TABLE I





FLOW DATA - PROCESS SEWER

GRAPH No. 1

SOURCE No.81 - DESALTER WATER

DATE	MONTH	JUNE 1971								NOV/71
	DAY	14	15	16	17	18	21	22	24	24
SAMPLED BY SUN-S, DILLON-D		S	S	S	S	S	S	S	S	D
pH		7·6	7·5	7·7	8·0	7·5	8·2	7·6	7·5	8·1
PHENOL (ppm.)		3·4	3·4	9	1·0	1·5	1·3	1·0	1·8	28·0
SUSPENDED SOLIDS (ppm.)		19	48	11	11	17	262	36	36	10
DISSOLVED SOLIDS (ppm.)		3177	3460	3948	3727	3832	4797	7968	4778	6781
OTHER ANALYSES	O(ppm.)	39·5	46·3	18·1	16·2	20·3	1826	3999	1880	1885(C)
	S(ppm.)	34	32	13	30	43	28	21	23	459
	Cl(ppm.)	1353	1454	1861	1861	1455	1320	990	1056	4520

SOURCE No.84 - FLARE SEAL DRUM WATER

DATE	MONTH	JUNE 1971			JULY 1971								OCTOBER 1971	
	DAY	25	28	29	8	9	12	13	14	15	16	19	20	4	4
SAMPLED BY SUN-S, DILLON-D		S	S	S	S	S	S	S	S	S	S	S	S	D	D
pH							7·2	8·7	8·7	6·0	9·0	8·2	8·7	8·4	8·5
PHENOL (ppm.)		6	56	0·5	0·07	0·5	0·06	0·08	0·10	0·60	0·09	0·04	0·05	0·56	0·50
OTHER ANALYSES	O(ppm.)													171(C)	193(C)
	S(ppm.)	18	Nil	Trace	Nil	Nil	Nil	Nil	·16	448	448	448	448		

SOURCE No.140 - PROCESS SEWER WATER

DATE	MONTH	APRIL 1971			MAY/71	JULY 1971								AUGUST 1971				SEPTEMBER 1971							OCTOBER 1971	
	DAY	7	9	19	26	18	12	13	14	15	16	19	20	27	4	10	24	31	23	27	29	29	30	30	30	1	1
SAMPLED BY SUN-S, DILLON-D		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	D	D	D	COMP D	COMP D	D	D	D	COMP D
pH		8·8	8·4	8·2	8·2	7·4	8·3	8·4	7·9	8·9	8·1	8·3	8·3	6·5	8·7	8·8	6·8	9·0	7·2	8·6	7·6	7·6	7·35	7·8	7·8	8·95	7·1
PHENOL (ppm.)		500	1700	1600	1200	330	4·5	1·7	2·0	1·7	1·0	1·7	1·3	0·7	1·0	1·2	1·3	3·8	3·7	4·0	2·9	3·7	3·3	5·4	3·2	4·95	3·5
SUSPENDED SOLIDS (ppm.)																			150	120	102	78	122	84	132	87	258
OTHER ANALYSIS	C (ppm.)																		565	910	548	639	889	524	649	323	891
	S (ppm.)	<1	<1		<1		Nil	43	37	7	115	45	53	17	3	Nil	8										
	P (ppm.)												1·4	4·4	3·4	2·4	7·2										

SOURCE No.145 - H_2S SUMP

DATE	MONTH	MAY 1971			JUNE 1971								SEPTEMBER 1971				OCTOBER 1971				NOV/71
	DAY	27	28	31	2	3	4	7	8	9	10	11	27	29	29	30	1	1	4	4	24
SAMPLED BY SUN-S, DILLON-D		S	S	S	S	S	S	S	S	S	S	S	D	COMP D	D	COMP D	D	COMP D	D	COMP D	D
pH		9·1	9·3	9·2	9·3	9·1	9·2	9·3	8·6	9·2	8·7	9·0	9·2	9·1	9·1	8·6	9·2	9·4	9·1	8·9	9·75
PHENOL (ppm.)		300	200	170	250	320	100	200	250	200	140	200	270	285	900	260	260	350	122	456	
SUSPENDED SOLIDS (ppm.)		13	163	254	18	59	9	44	17	73	10	9	180	148	705	210	187	577	62		
DISSOLVED SOLIDS (ppm.)		190	344	459	3070	97	625	111	857	132	294	276	172								
OTHER ANALYSIS	C (ppm.)												14,682	18,848	23,411		20,270	25,584	17,906	28,334	1,788
	S (ppm.)	1850	1540	2926	2000	770	3850	4315	1694	2849	3619	4697	3262								*284
	N (ppm.)	2948	2930	2774	3069	2930	3398	2878	2705	3485	3363	2272	3000								

ABBREVIATIONS

COMP - COMPOSITE SAMPLE
O - OIL
C - C.O.D.
S - H_2S
Cl - CLORIDES
P - PHOSPHORUS
N - AMMONIUM NITROGEN
Na - SODIUM
* - AFTER STRIPPING

SOURCE No.129 - CRUDE ACCUMMULATOR WATER

DATE	MONTH	JULY 1971						
	DAY	12	13	14	15	16	19	20
SAMPLED BY SUN-S, DILLON-D		S	S	S	S	S	S	S
pH		4·9	6·4	7·0	7·1	6·5	7·7	7·7
PHENOL (ppm.)		1·5	2·5	4·5	2·5	2·5	3·3	1·7
OTHER ANALYSES	S(ppm.)	50	208	224	122	240	160	442

SOURCE No.157 - DILUTE CAUSTIC SUMP

DATE	MONTH		NOVEMBER/71	
	DAY		24	24
SAMPLED BY SUN-S, DILLON-D		S	D	D
pH			12·8	
PHENOL (ppm.)		370	900	
SUSPENDED SOLIDS (ppm.)			400	
DISSOLVED SOLIDS (ppm.)		820	4370	
OTHER ANALYSIS	C(ppm.)		14,536	
	S(ppm.)		2565	
	(ppm.)		2190 Cl.	4370 Na

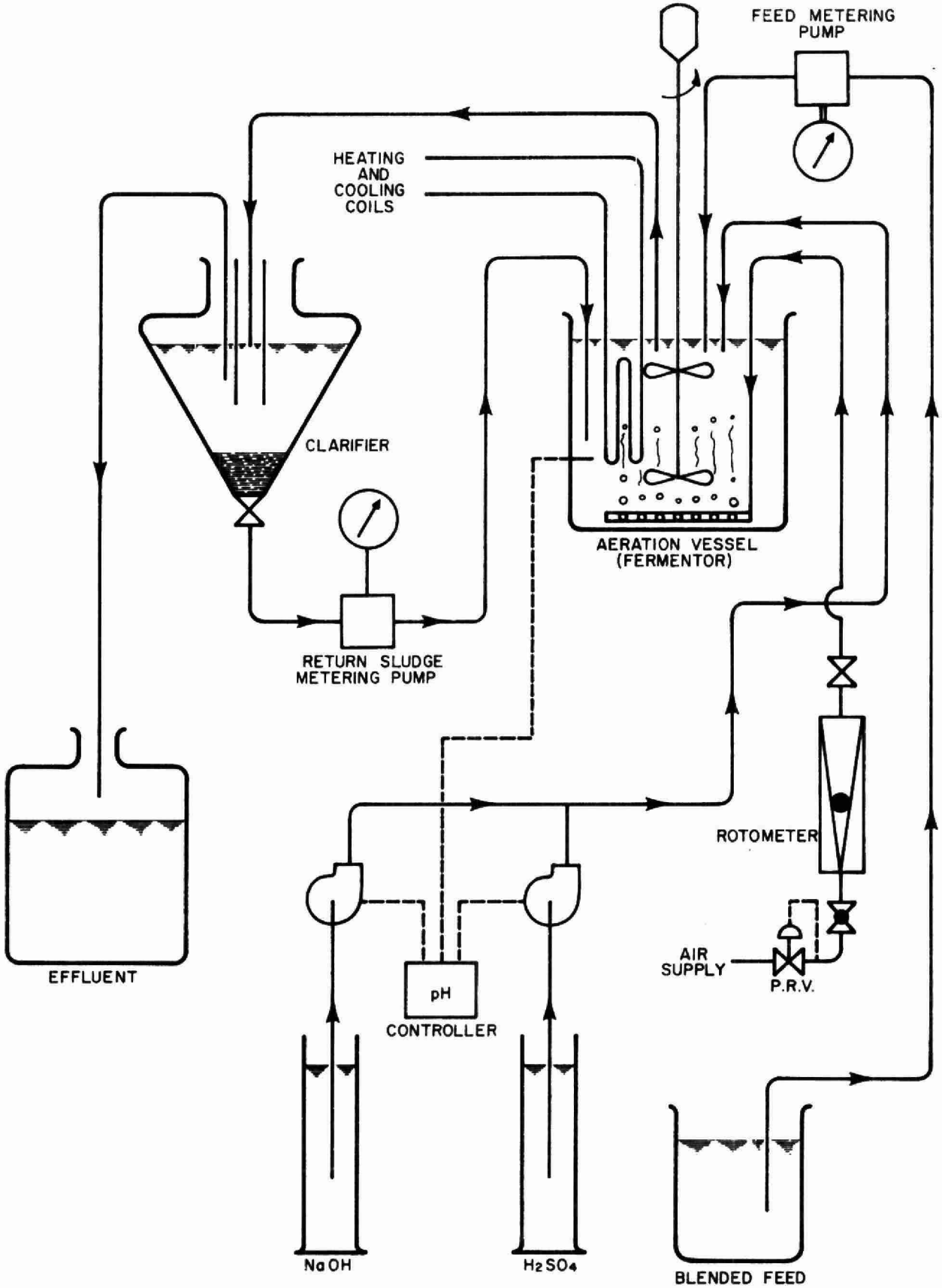
SOURCE No.171 - TANK BOTTOMS

(AVERAGE CONCENTRATION FOR BOTTOMS FROM TANKS 4,5,10,14,17,18,19,21,22,23)

DATE	MONTH	25/5/71 TO 23/6/71	NOVEMBER/71	
	DAY		24	24
SAMPLED BY SUN-S, DILLON-D		S	D	D
pH		12·0	8·8	
PHENOL (ppm.)		560	540	
SUSPENDED SOLIDS (ppm.)			21	
DISSOLVED SOLIDS (ppm.)		20,000	40,000	
OTHER ANALYSIS	C(ppm.)		9384	
	Ca(ppm.)	7500	41,313	
	Na(ppm.)			19,400

SUMMARY OF RESULTS OF ANALYSES AT SOURCES

TABLE No. 11



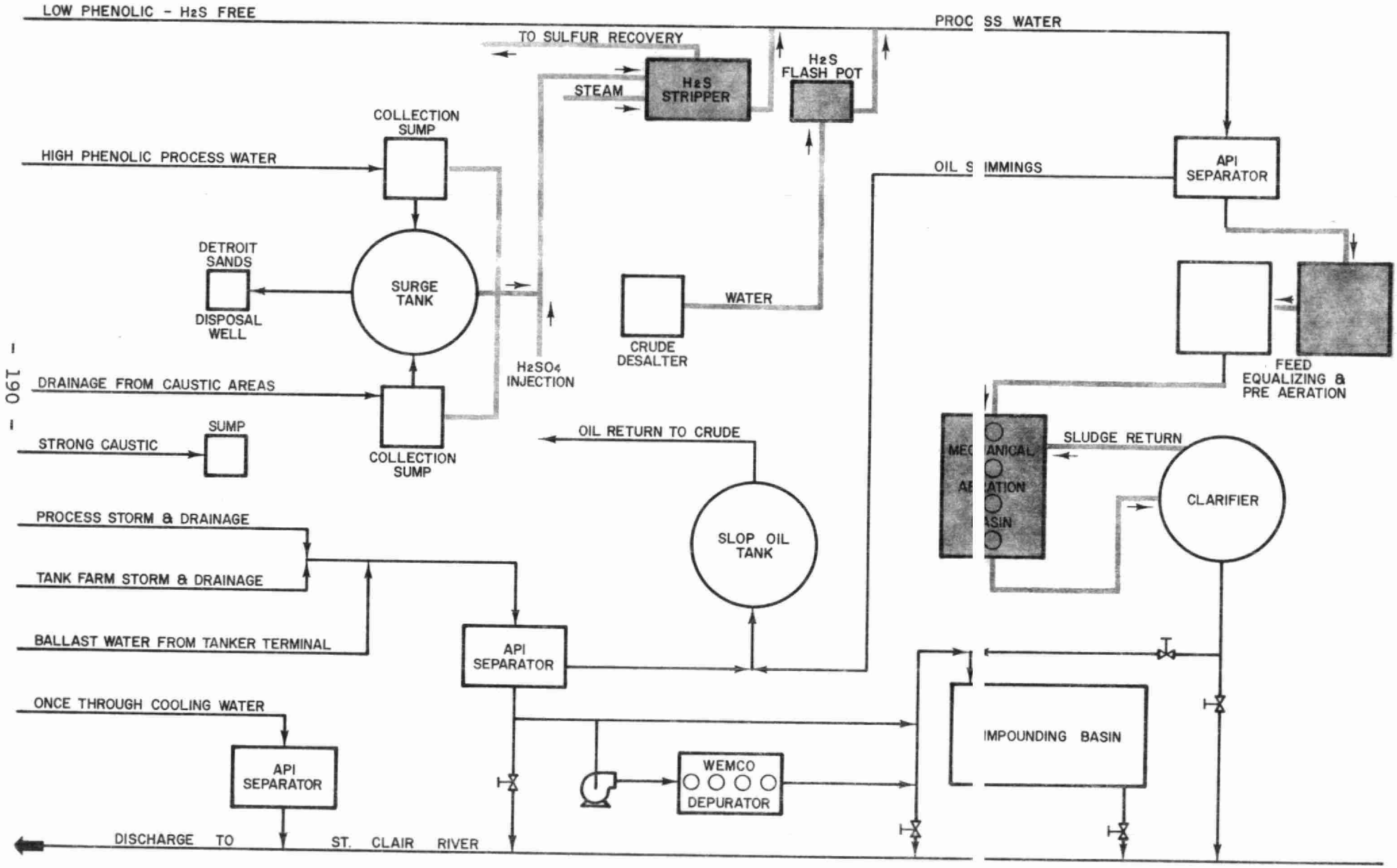
SCHEMATIC OF LABORATORY APPARATUS

FIGURE VI

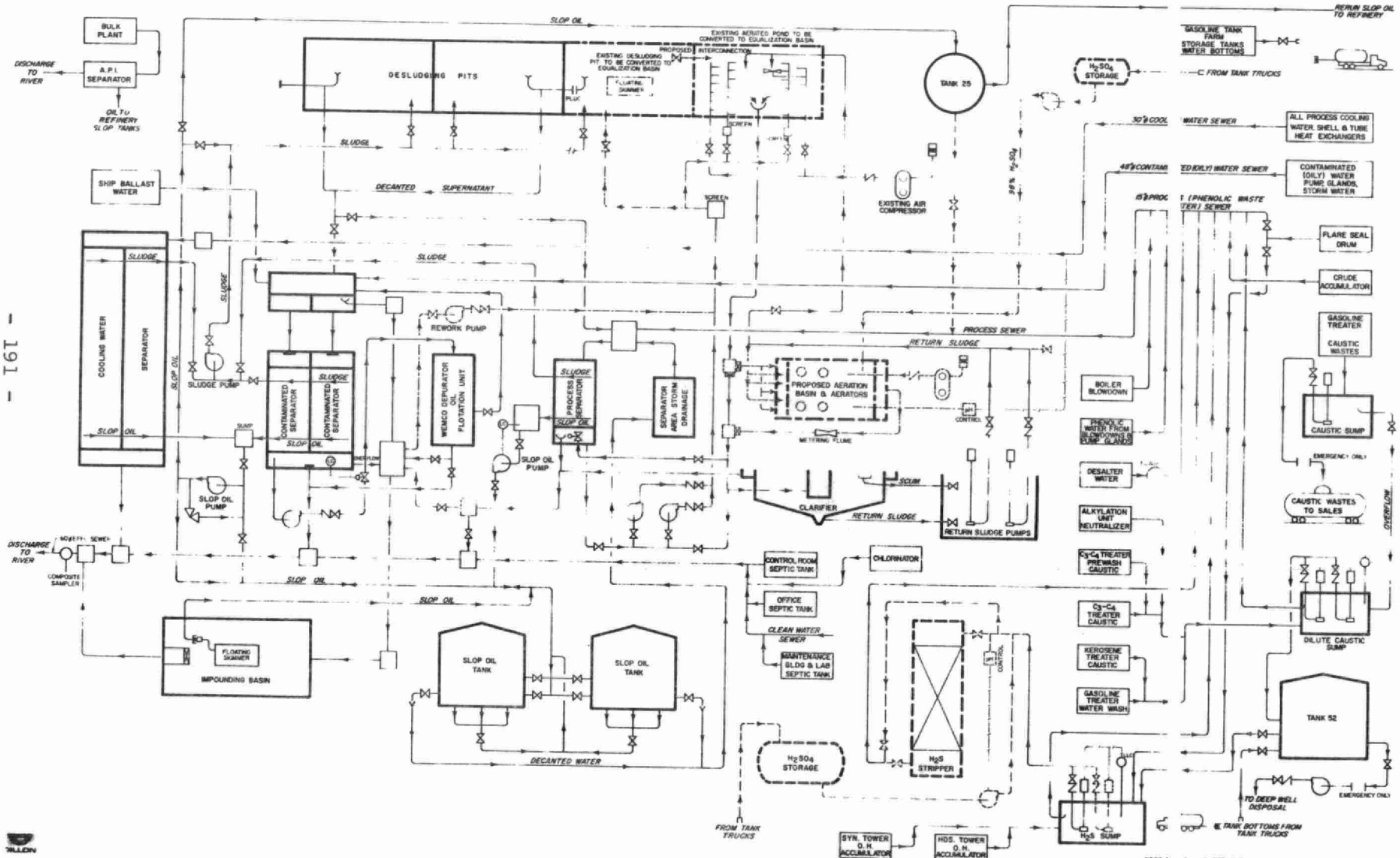
PHENOL IN FEED:	120 ppm.
COD IN FEED:	2,000 ppm.
FEED BOD/COD:	0.5 – 0.6
MLSS:	2,000 mg./LITRE
RETURN SLUDGE RATIO:	0.25
DETENTION TIME:	24 HOURS
SVI:	85 TO 100
MLVSS/MLSS:	0.66
OVERFLOW RATE (SLUDGE SEDIMENTATION):	1,150 I. gal. per day/ft.
O_2 UPTAKE RATE:	70 mg./l./hr.
b' FACTOR:	0.227 lb. O_2/day per lb. MLVS
α FACTOR = $\frac{(K_La \text{ SETTLED EFFLUENT})}{(K_La \text{ TAP WATER})}$:	0.66
β FACTOR + $\frac{(C_S \text{ SETTLED EFFLUENT})}{(C_S \text{ TAP WATER})}$:	1.0
OPERATING TEMPERATURE:	25° C±
OPERATING pH.:	7± 0.2 UNITS
NUTRIENT REQUIREMENTS:	NITROGEN – SUFFICIENT IN WASTE WATER
	PHOSPHORUS – ONE lb. OF PHOSPHORUS per 90 lb. BOD REMOVED

SUMMARY OF DESIGN PARAMETERS DETERMINED FROM LAB BENCH SCALE TESTING

TABLE III



ADDITIONS TO WASTE WATER TREATMENT FACILITIES AFTER TREATAB LITY STUDIES FIGURE VII



WAS E WATER - FLOW SCHEMATIC
FIGURE VIII

PARAMETER	DESIGN EXPECTATIONS	OPERATIN	DATA
FLOW OF WASTE	273 USGPM	400 – 50(	USGPM
PHENOLS IN INFLUENT (ppm.)	120	52	
PHENOLS IN EFFLUENT (ppb.)	< 200	191	
PHENOL REMOVAL lbs/day	470	33	
MIXED LIQUOR SUSPENDED SOLIDS ppm.	2000	150	
RATIO MLVSS/MLSS	0·66	0·7	
SLUDGE VOLUME INDEX	85 – 100	89	

COMPARISON OF ACTUAL OPERATING DATA VERSUS PREDICTED OPERATING DATA

TABLE IV

COMPONENT	PROVINCIAL (I.J.C.) GUIDELINES	REFINERY EFFLUENT BEFORE NEW TREATING FACILITIES	REFINERY EFFLUENT AFTER NEW TREATING FACILITIES	P FEDE EXIS	OPOSED NEW RAL GUIDELINES TING REFINERY	REFINERY EFFLUENT EXISTING REFINERY
PHENOLS	20 ppb.	44 ppb.	14 ppb.	0·6 lb	/1000 Bbls. CRUDE	0·08 lbs./1000 Bbls. CRUDE
OIL AND GREASE	15 ppm.	4 ppm.	3 ppm.	6·0 lb	/1000 Bbls. CRUDE	16·5 lbs./1000 Bbls. CRUDE
SUSPENDED SOLIDS	15 ppm.	9 ppm.	13 ppm.	14·4 lb	/1000 Bbls. CRUDE	71·5 lbs./1000 Bbls. CRUDE
SULPHIDES		0·3 ppm.	NIL ppm.	0·2 lb	/1000 Bbls. CRUDE	
NITROGEN OR AMMONIA N.	1 ppm.	1 ppm.	5 ppm.	5·0 lb	/1000 Bbls. CRUDE	27·5 lbs./1000 Bbls. CRUDE
pH	5·5 – 10·6	8·0	8·1		6·0 – 9·5	8·1
B.O.D.						
C.O.D.		33 ppm.	20 ppm.			
DISSOLVED SOLIDS	1500 ppm.	272 ppm.	300 ppm.			
DISSOLVED OXYGEN	4 ppm. MIN.	8 ppm.				
IRON		0·1 ppm.	0·1 ppm.			
PHOSPHORUS		0·5 ppm.	0·1 ppm.			

COMPARISON OF REFINERY EFFLUENT BEFORE & AFTER INS TALLATION OF NEW TREATING FACILITIES VERSUS GOVERNMENT REGULA TIONS

TABLE V

TOTAL REFINERY INVESTMENT (1953 TO 1972)	$ 40,000,000	
INVESTMENT FOR WASTE TREATMENT FACILITIES (1953 TO 1970)	$ 2,500,000	
PERCENTAGE OF TOTAL INVESTMENT		6·3 %
INVESTMENT FOR WASTE TREATMENT FACILITIES (1970 TO 1972)*	$ 1,080,000	
PERCENTAGE OF TOTAL INVESTMENT		2·7 %
INVESTMENT FOR REFINERY EXPANSION 1973	$ 32,300,000	
INVESTMENT FOR WASTE TREATMENT FACILITIES 1973	$ 610,000	
PERCENTAGE OF INVESTMENT FOR REFINERY EXPANSION		1·9 %

* INCLUDES EXTRA CAPACITY FOR 1973 EXPANSION

SUMMARY OF CAPITAL COSTS

TABLE VI



CHAIRMAN - SESSION IV,
MR. R. M. COOPER,
CHEMICAL ENGINEER,
CANADIAN INDUSTRIES LIMITED,
MONTREAL, P.Q.



J. B. Knapp

WATER RECLAMATION AND RE-USE AT BRENDA MINES LIMITED

BY

J. B. KNAPP,
CONCENTRATOR SUPERINTENDENT

AND STAFF OF
BRENDA MINES LIMITED,
PEACHLAND, B.C.

The copper-molybdenum property of Brenda Mines Ltd., a member of the Noranda Group, is located 50 miles north of the International Boundary and 150 air miles east of Vancouver, and lies in the Okanagan valley. The area, known as the southern interior of British Columbia, is separated from the west coast by the mountain ranges and high plateaux of the Coast Range system of mountains. These mountains intercept most of the moisture carried by the weather systems approaching from the Pacific Ocean, and consequently, the southern interior is a semi-arid region.

The average annual precipitation is less than 15 inches, and almost all falls as winter snow.

The valley of the Okanagan Lake System, located east of these ranges and plateaux, enjoys a rather equable climate. With reasonably mild winters, and dry, warm summers the area is well-suited to the cultivation of tree fruits, grapes, and forage crops. The only requirement not provided by nature is an adequate supply of water during the growing season.

From the earliest days of settlement in the 1860's this one shortcoming has been overcome by the development of irrigation systems. The surrounding plateaux, rising to the 5000 - 6000 foot elevation and subjected to a regular winter snow cover, have been utilized to provide a year-round dependable supply of domestic and irrigation water. Almost every lake and stream has been adapted to the storage of run-off from the winter snow. Because of the complete dependence of this stored water, the long-standing water licenses are jealously-guarded, and requests by others for water are scrutinized very closely.

A more recent development in the valley of the Okanagan, again the result of the climate, is the tourist trade. This business also makes use of the lakes and streams, and any proposal for industrial development is studied closely because even a suspicion of water pollution could adversely affect the seasonal influx of tourists.

It was with these conditions and constraints that Brenda Mines was conceived. It is understandable if limitations imposed on the project, both for storage of tailings and their contained water, and for diversion and storage of fresh water, have been more stringent than those imposed upon most mines in the past. One such condition which faced the operations was the specific prohibition of any downstream discharge from the milling facilities imposed by the Province of British Columbia Pollution Control Board. No mine in history has had to contend with such a situation before.

Partial reclamation of water used in milling processes has been employed for years by many mines in many countries. It was an accepted practice long before conservation and pollution control became fashionable simply as a matter of economics, or to overcome a local water shortage. Varying amounts of water are reclaimed by these other mines depending on their local conditions, the cost and availability of water, and upon the chemicals used in their processes. However, Brenda Mines is the only mining company in Canada, perhaps in the world, which maintains a completely closed system with no discharge from the tailings pond. This fact must always be borne in mind when new chemicals are considered for use in the concentrator, because some traces of them or their decomposition products will be present for long periods of time. This has restricted the use of reagents in the concentrator which could be beneficial to the process on a once-through basis, but could not be tolerated when returned through the reclaim water.

Brenda Mines Ltd. is an open pit mine, and the concentrator is designed to process 24,000 tons per day of a very low grade ore by a flotation process. The products of the operation are a copper

concentrate containing approximately 26% copper, a molybdenum concentrate containing approximately 56% molybdenum, and a waste material called tailings. The tailings, which comprise more than 99% of the weight of ore treated, are discharged from the concentrator in the form of a water slurry. It is this material and the contained water which must be impounded to comply with the Pollution Control Board permit which prohibits any downstream discharge.

Flotation concentrators are large users of water, and the Brenda concentrator requires approximately 15×10^6 gallons per day. Obviously, it would be impractical, if not impossible, to store all this water over the 20-year anticipated life span of the mine, and re-use of the water was therefore necessary. Provision of a continuous fresh water supply of this magnitude was equally impractical, although the fresh water system which was developed is capable of more than present requirements.

Any discussion of the use of reclaim water must, of necessity, include a brief description of the tailings disposal system, and the method used for recovering the water content.

Tailings leave the concentrator in the form of a water slurry containing approximately 30% solids by weight, and flow by gravity through 30-inch diameter pipe for a distance of two and one-half miles to the tailings disposal area. Here the slurry is classified by hydrocyclones, and separated into a coarse, sandy free-draining fraction which contains little water, and a fine, slimy product containing most of the water. The sandy material is used for dam building, and the fines are distributed along the upstream face of the dam where they gradually settle to form an impervious seal for the dam and retain the pond of water which forms as the fines settle. It is this water that is reclaimed and pumped back to the concentrator for re-use.

The initial construction for the tailings dam comprised two rock toe-dams placed in the valley of an unlicensed creek which had been diverted to the fresh water storage area. The toe-dams, located 1200 feet apart, were 3000 feet long, and built to heights of 110 feet and 185 feet with rock stripped from the pit area during the development stage. The upstream face of the upstream dam was made impervious by a layer of compacted glacial till, and formed a catch basin for run-off waters in the spring of 1969 which provided the water requirements necessary for the start-up of the concentrator later that year. The available supply of fresh water and its associated pumping system are inadequate for operation, and a reserve of water was required in the tailings (reclaim) storage area. In this location it was available to the much larger reclaim pumping system designed to provide the full requirements of the concentrator.

Dam building is now carried on by hydraulically-placed cycloned sands, and supplemented by bulldozers and scrapers. The space between the rock toe-dams is gradually filling with the classified sands, and the upstream crest is maintained at an elevation sufficient to retain the fine slimy portion of the tailings and the water used in processing. Construction of the dam with free-draining sands and the widely-spaced rock toes were required to assure overall dam stability in the mild earthquake zone in which the operation is located.

Hydraulic transport water, used for the placement of the sands, drains through the sands and the pervious lower rock toe to a smaller and impervious lower dam from where it is pumped back to the main tailings area. The ultimate size of the sand dam will be approximately 450 feet in height, more than 6000 feet long, and 1200 feet wide at the base.

The water which gathers after the fines and slimes have settled is pumped back to the concentrator for re-use. Two vertical turbine pumps are mounted on each of two barges floating on the pond surface, and discharge to two shore pumping stations in series which elevate the water to a 500,000 gallon tank located above and near the concentrator.

Approximately 11,000 gpm, which amounts to more than 90% of the water requirements of the plant, are met by this reclaim system. Less than 1000 gpm of fresh water are used to satisfy the requirements of the process where fresh water was found to be essential, and for the domestic or sanitary needs for a work force of close to 400 people.

An estimated 75% to 80% of the total water entering the tailings area from all plant sources becomes available for re-use after the solids have settled. The remaining water is permanently retained by the settled solids, or lost through evaporation. Water additions to the system are therefore necessary, but these additions must be carefully controlled to avoid exceeding the storage capacity of the dam.

An unpredictable quantity of additional water enters the pond annually in the form of the spring run-off from the drainage basin containing the tailings area. Run-off waters can flood into the reservoir very quickly, and the dam must be in condition to accept and store this water whenever it arrives. It is this annual inflow of up to 1500 acre feet or more which currently limits the use of fresh water to less than 1000 gpm. A greater usage would outstrip the present slowly-increasing storage capacity of the dam.

The pond area is surveyed twice each year to determine the volume of water contained, and to provide ample warning of any tendency of the water to accumulate. The volume of water in the tailings pond in October, 1972 totalled 2250 acre feet after a record run-off in the spring of 1972, and the volume of free water in May, 1973 was 2025 acre feet. The surface area of the pond water is currently 180 acres, with an average depth of slightly more than 11 feet. The maximum depth of the pond in the May, 1973 survey was 32 feet, and the pond surface has risen 103 feet since milling commenced in the fall of 1969.

The flotation process at Brenda Mines requires the use of sodium isopropyl xanthate, potassium amyl xanthate, and the allyl ester of amyl xanthate for recovery of the copper minerals, and stove oil is used as a collector for the molybdenum minerals. Sodium hydrosulphide is used for the separation of chalcopyrite from molybdenite, and sodium cyanide is used to inhibit the flotation of pyrite, and also to aid in the final separation of chalcopyrite and molybdenite.

In addition to the flotation process, Brenda also periodically employs a leaching process for further purification of the molybdenite concentrate. This process requires a strong brine consisting of calcium chloride, ferric chloride, cupric chloride, and hydrochloric acid to achieve pH approaching zero. The process removes copper, lead, and iron sulphides from the molybdenite concentrate as well as any calcium or magnesium carbonates which are usually present in minor amounts.

All of these chemicals find their way in varying amounts into the tailings system, and thus into the reclaim water. They, and their decomposition products, are all returned to the concentrator with the water where they are now introduced indiscriminately to all areas of the process, including those areas where they can be undesirable and even detrimental. Fortunately, oxidation reactions in the tailings pond change most of the reagents used by Brenda into relatively inactive decomposition products, some of which are retained by the settled solids.

Some of the reagents, notably the frothers, are returned by the reclaim water in their original form, and the use of water which already contains frother in a flotation circuit can be very harmful. Excessive frothing causes low concentrate grades, spills onto floors which require additional labor for clean-up, and even metal losses. The type of frother used must also be considered. Alcohol-type frothers, such as the one in use, are sometimes less effective for metal recovery when compared with the polypropylene glycol or pine oil types, but they are subject to partial evaporation in the tailing pond and are therefore preferred.

Weather conditions contribute to the effect of returning reagents in the reclaim water. During winter months when the surface of the pond is frozen, less oxidation occurs and more reagent is returned to the concentrator. This is particularly noticeable in the case of xanthate, frother, and cyanide. Return of reagents in reclaim water is said to reduce the requirements for ore currently being treated and therefore reduces current operating costs. This is true to some extent, but on occasion even greater quantities of new reagents are needed to overcome the effects of a reagent that has been introduced at the wrong point of the process.

Reclaim water is used at Brenda Mines during wet grinding of the ore, in rougher flotation circuits which make the primary recovery of the copper and molybdenum minerals, and in the early stages of the separation circuits where the minerals are separated from each other. It has not been possible to use reclaim water in the copper or molybdenum cleaner flotation circuits where upgrading to make a saleable concentrate is performed. In these areas reclaim water produces wild and uncontrollable frothing, and concentrates produced under these conditions are completely unacceptable. Such concentrates cannot meet the most generous sales or smelter specifications, and fresh water must be used during cleaner flotation. One of the few benefits derived from being a very low grade mine is the production of a relatively small amount of concentrate which consequently requires a low volume of fresh water in cleaner circuits.

Due to a varying and sometimes high content of suspended solids, reclaim water is also unsuitable for use in compressor or vacuum pump cooling jackets, in water-seal glands on slurry pumps, and in other places where solids contained in the water can plug passages or cause abrasive wear to equipment.

Among other factors to be considered in the use of reclaim water by a mine are the following:

1) The necessity and capital cost of two completely separate pumping and piping installations.

2) The necessity and cost of providing excessive dam capacity to store safely an unpredictable inflow of run-off water in cases where no discharge is permitted. Dam capacity requires a long lead time for preparation, and it must always be sufficient to store water from a year of peak snowfall even though the average requirement is much lower.

3) Scale formation in pipelines and equipment, and attack on brass valves and fittings from the high dissolved solids content of the water.

4) The seasonal changes in the character and chemistry of reclaim water. Ice formation in cold weather reduces oxidation and evaporation of reagents, and greater amounts are returned to the mill with sometimes harmful effects on concentrate grade or metal recovery. Spring brings the run-off water from melting snow and the beneficial effects of a large dilution factor, but again the change upsets a sensitive flotation circuit and can result in poorer metallurgy.

5) Foreign material such as pineneedles, tree bark, and wood chips are flushed into the water system from the banks of the storage basin by a continually rising pond level. The level of the water surface of the Brenda tailing pond has risen 103 feet since the start of operations in the fall of 1969.

The use of reclaim water at Brenda Mines is primarily the result of necessity rather than by choice. There are drawbacks to its usage, which have been pointed out, but under our conditions it has been possible to minimize or overcome many of these effects. Experience to date indicates that fresh water will always be required for particular purposes, but careful control has reduced the consumption to a point that is acceptable yet thus far lies within the limits of our ability to provide storage. This may not be possible under different conditions.

A particularly fortunate circumstance lies in the nature of the copper-molybdenum separation process using sodium hydrosulphide. This chemical is rapidly oxidized under flotation and tailing pond conditions, and has never been detected in the reclaim water entering the concentrator. If it were, the chemical would seriously interfere with primary copper recovery, and preclude operation of the plant as a closed circuit.

With no available history of operation in the manner which Brenda contemplated, the decision was taken long before start-up to make frequent and detailed analyses of the water used in the milling process. The mine laboratory was provided with equipment that could perform most of the analyses required, but samples are sent elsewhere for determinations requiring the use of more specialized equipment. Additions to and deletions from the analysis program have been made from time to time in an effort to delineate those parameters which had a pronounced effect upon mill performance. Apart from seasonal differences, the variations due to dilution by run-off water, or changes in the consumption of various reagents in the mill, no

detectable trends have been evident which could explain erratic concentrator performance at times. Most of these occurrences have coincided with the February-March periods when the pond is ice-covered and residual reagent concentrations are at a peak.

In addition to the analysis of reclaim water the laboratory analyzes waters from the surrounding area, both above and below the mine, which could be influenced by the operation. Similar analyses of duplicate samples by an independent laboratory have been performed monthly since 1968 before construction was undertaken or operation commenced. The statement can be made in all confidence that the environmental effects from the operation of the mine are at worst negligible, and more likely there has been no effect.

LOCAL FRESH WATER ANALYSIS

Parameter	Above Area of Influence of Mine		Below Area of Influence of Mine	
pH	7.3 - 8.4		7.3 - 8.5	
Suspended Solids	1 - 5	MGM/L	1 - 10	MGM/L
Dissolved Solids	44 - 130	MGM/L	40 - 184	MGM/L
Conductivity	76 - 190	mhos	70 - 260	mhos
Chloride	1	MGM/L	1	MGM/L
Sulphate	1 - 5	MGM/L	4 - 8	MGM/L
Total Hardness as $CaCO_3$	35 - 89	MGM/L	36 - 94	MGM/L
Phosphate	0.2	MGM/L	0.2	MGM/L
Total Cyanide	0.01	MGM/L	0.01	MGM/L
Total Alkalinity	4 - 6	MGM/L	4 - 6	MGM/L
Phenolphthalein Alkalinity	Not detected		Not detected	
Calcium	10 - 33	MGM/L	10 - 33	MGM/L
Copper	0.01	MGM/L	0.01	MGM/L
Molybdenum	0.01	MGM/L	0.01	MGM/L
Lead	0.01	MGM/L	0.01	MGM/L
Iron	0.02 - 0.10	MGM/L	0.02 - 0.11	MGM/L
Zinc	0.01	MGM/L	0.01	MGM/L
Chromium	0.01	MGM/L	0.01	MGM/L
Arsenic	0.01	MGM/L	0.01	MGM/L
Boron	0.2	MGM/L	0.2	MGM/L

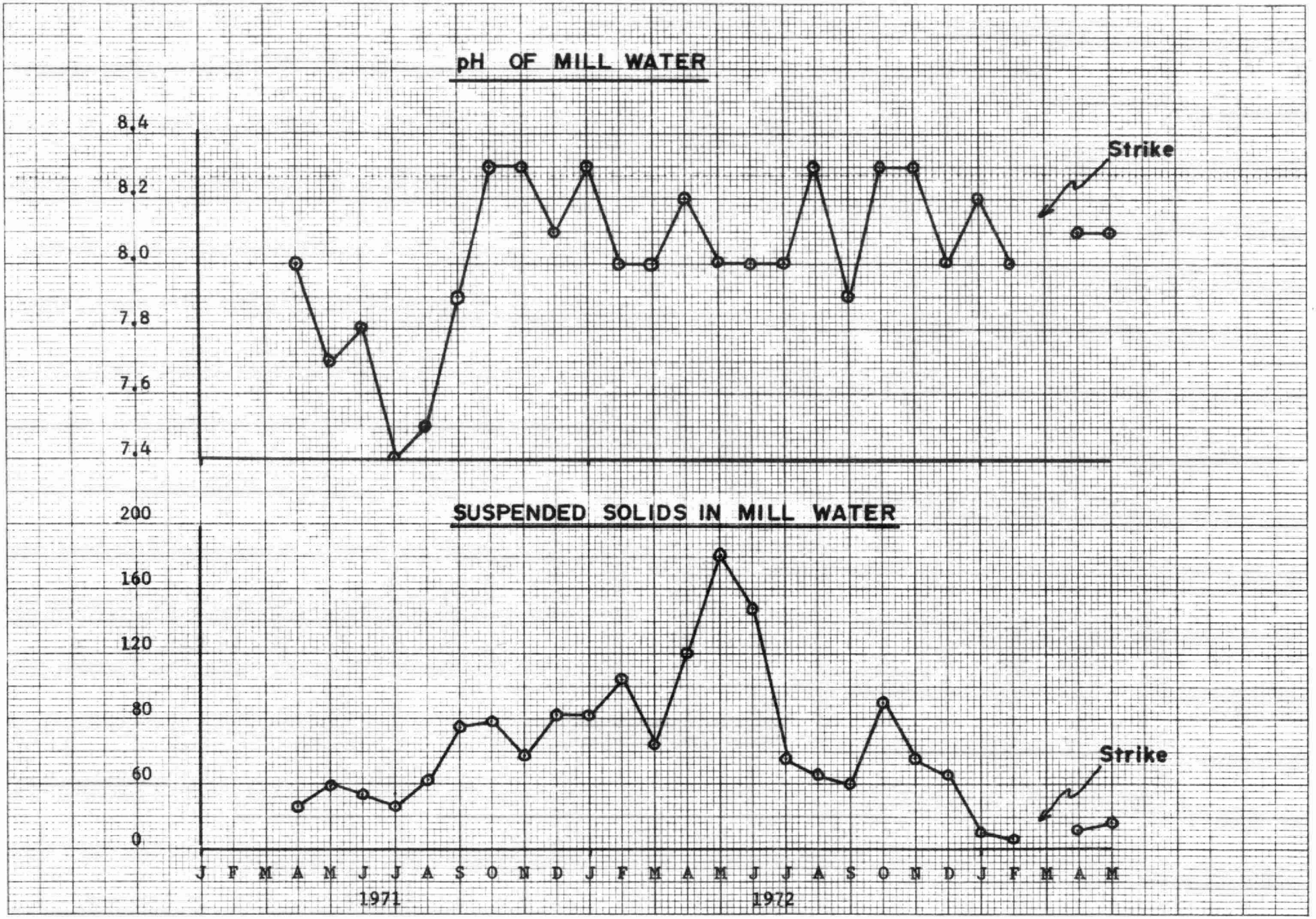
TYPICAL RECLAIM WATER ANALYSIS

Parameter	Range	Comments
pH	7.4 - 8.3	Low readings appear to be associated with Leach Plant operation. No apparent seasonal variations.
Suspended Solids	8 - 200 MGM/L	Low suspended solids associated with Leach Plant operation. High values associated with Spring Run-off and Leach Plant not operational.
Dissolved Solids	400 - 1,000 MGM/L	Derived by calculations from conductivity. Varies with operation of Leach Plant and shows seasonal changes.
Conductivity	500 - 1,300 mhos	
Chloride	25 - 140 MGM/L	Vary with Leach Plant operation.
Calcium	40 - 130 MGM/L	
Sulphate	150 - 350 MGM/L	Recent modification in Mill operation resulting in a decrease in the consumption of NaHS appear to have levelled this off at 250 MGM/L but it is expected that there will still be seasonal variations.
Total Hardness	94 - 350 MGM/L	This value is calculated from the calcium and magnesium values and therefore varies with Leach Plant operation.
Phosphate	0.2	
Total Cyanide	0.01 - 3.0 MGM/L	Fluctuates with ice cover on tailings pond. High readings obtained during winter; .01 MGM/L during summer.
Total Alkalinity	7 - 9 MGM/L	
Phenolphthalein Alkalinity	Not detected	

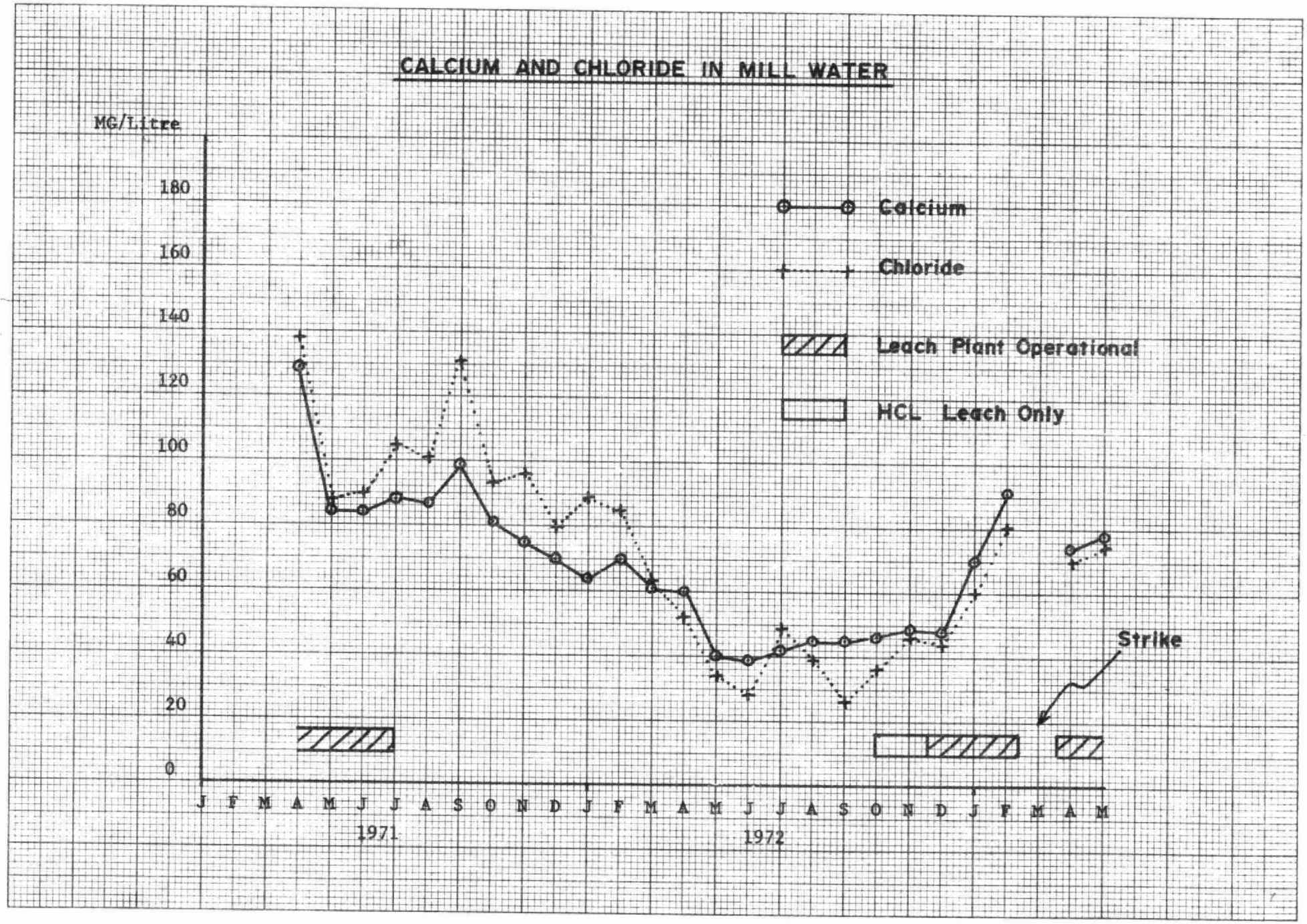
TYPICAL RECLAIM WATER ANALYSIS

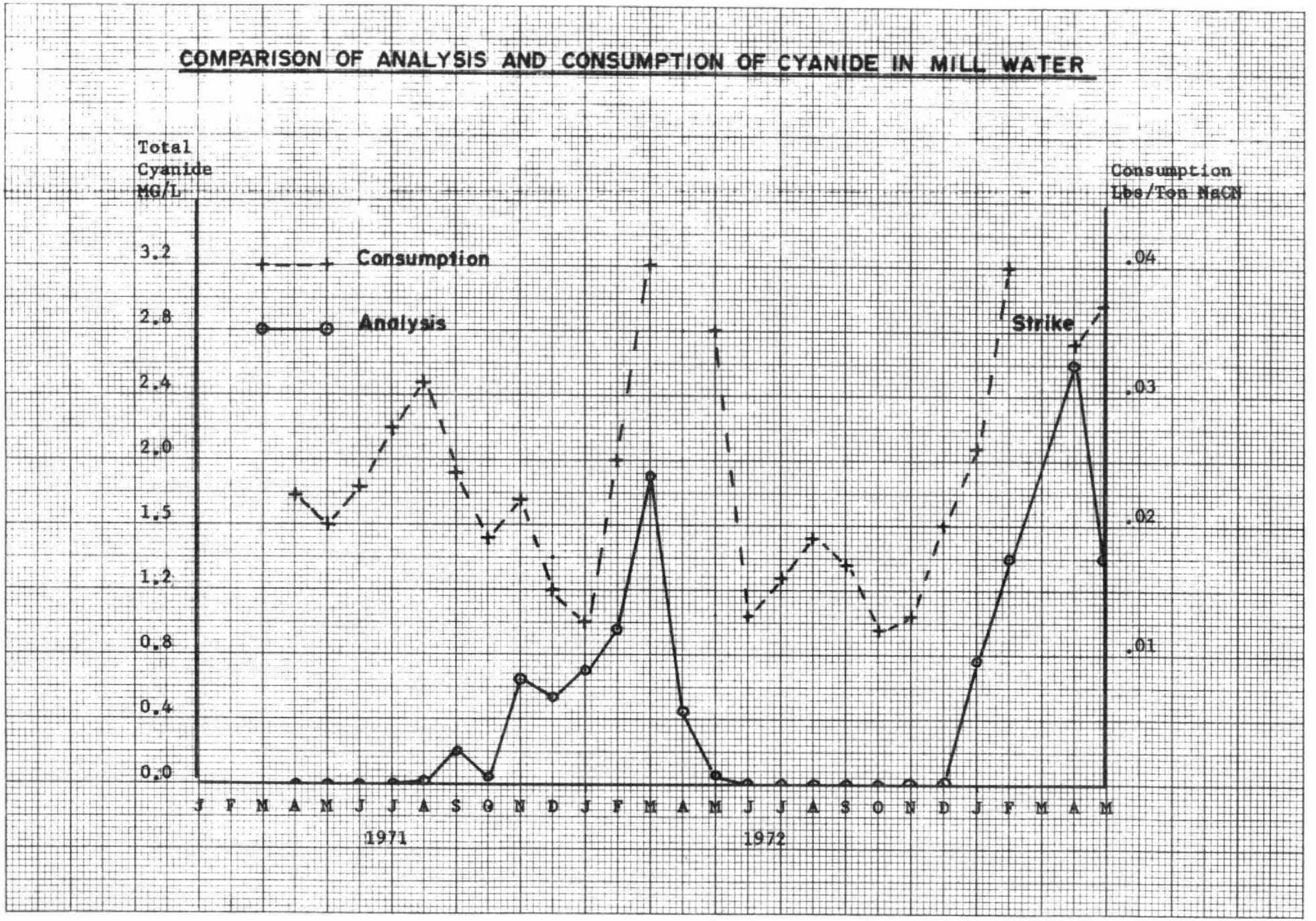
METALS

Parameter	Range	Comments
Copper	0.01 - 2.0 MGM/L	Varies with Spring Run-off and Leach Plant operations.
Molybdenum	0.10 - 0.70 MGM/L	Appears to be relatively constant in the 0.60 - 0.70 MG/L range except when diluted by run-off water.
Lead	0.01 - 0.02 MGM/L	
Iron	0.01 - 0.02 MGM/L	
Zinc	0.03 - 0.16 MGM/L	
Chromium	0.01 MGM/L	
Arsenic	0.01 MGM/L	
Boron	0.2 MGM/L	

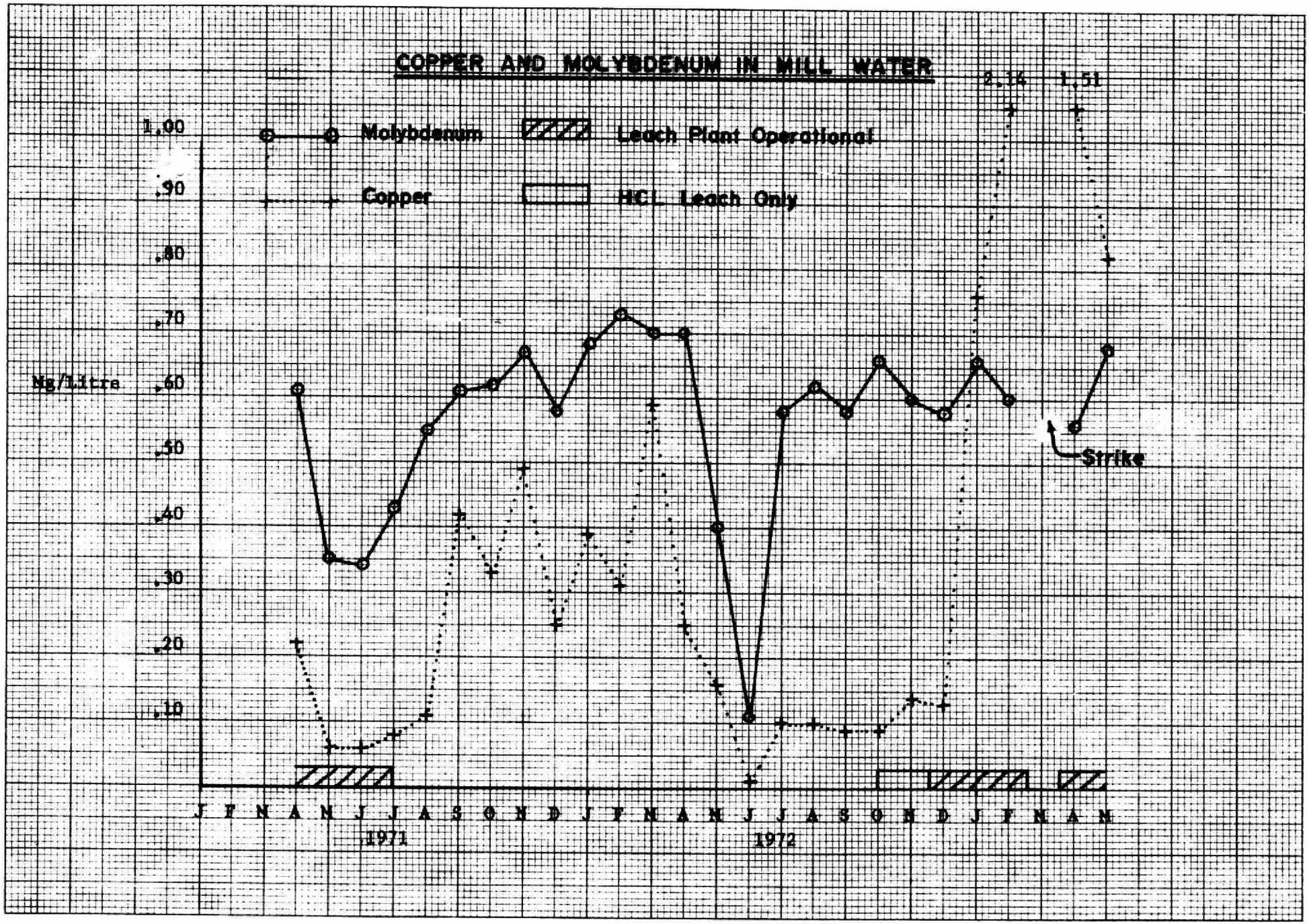

pH OF MILL WATER
8.4
8.2
8.0
7.8
7.6
7.4
Strike
SUSPENDED SOLIDS IN MILL WATER
200
160
120
80
60
0
Strike
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
1971
1972

K+E 10 X 10 TO ½ INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.




COMPARISON OF ANALYSIS AND CONSUMPTION OF CYANIDE IN MILL WATER
Total Cyanide MG/L
Consumption Lbs/Ton NaCN
3.2
2.8
2.4
2.0
1.5
1.2
0.8
0.4
0.0
.04
.03
.02
.01
Consumption
Analysis
Strike
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
1971
1972

K+E 10 X 10 TO ½ INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.





P. G. Belling

THE PROVINCE OF ONTARIO CONTINGENCY PLAN - 1973 STATUS REPORT

BY

P. G. BELLING,
CONTINGENCY PLANNING OFFICER,
INDUSTRIAL WASTES BRANCH,
MINISTRY OF THE ENVIRONMENT,
TORONTO.

Gentlemen, during the presentation of this paper, someone, somewhere in Ontario will probably be responsible for a spill of a deleterious substance. With luck, the substance will probably not present a hazard to people, but invariably the spill will present a hazard to our environment to a greater or lesser extent. In all likelihood the spill will be promptly and properly cleaned up. Damage to the environment will be minimized because some person or a group of persons have taken the time to prepare an action plan which outlines what to do in the event of a spill; someone has prepared a contingency plan for spills of deleterious substances. Despite these plans of preparedness, questions are still being raised occasionally along the lines of "why the Ministry of the Environment is not doing something" about a given spill. Often these questions have the implication that this Ministry should be at the spill site cleaning up. Well, gentlemen, contrary to the belief of some, the Ministry of the Environment is not in the spill clean-up business. Often, when we are notified of a spill, nothing more may be required initially on our part than making one or two telephone calls.

The purpose of this paper then is to present the current status of contingency planning in Ontario, to delineate who is engaged in the clean-up of spills, and to indicate the involvement of the Ministry of the Environment in spill incidents.

HISTORY OF CONTINGENCY PLANNING IN ONTARIO

In Ontario, contingency planning for spills of oil was begun at the Provincial Government level in late 1969 as a result of concern being expressed about gas well drilling operations on Lake Erie, and because of recommendations made by the IJC that programs were required to prevent the discharge of oil and to improve the capability for control and clean-up in the event of spills.

The initial contingency plan, for Lake Erie, was published by the OWRC in April, 1970 and this was followed six months later by the Province of Ontario Contingency Plan in its preliminary form. After incorporating comments received from industry and other government agencies, the "Interim Province of Ontario Contingency Plan for spills of oil and other hazardous materials" was published in May, 1971 superseding both the Lake Erie and Preliminary Province of Ontario contingency plans.

The interim plan, developed as it was within the OWRC, is limited in scope to those spills which may affect the surface or ground waters of the Province. Spills whose sole effect may be on air or land are therefore not presently covered by the plan.

Under the Provincial plan, the development of local plans of preparedness are encouraged. Contingency plans have been developed by some municipalities, and a number of the larger industries or industry groups. A number of very effective industry cooperatives have also been established, and these cooperatives have played important roles in providing a response capability for smaller spills and "first aid" for larger spills.

In the event of spills which require resources beyond those available to the Province, the Canadian Federal Government could be requested to provide assistance under the "Federal Contingency Plan".

For those spills which threaten to pollute international waters in the Great Lakes system, Ontario has accepted certain responsibilities under the "Joint U.S. - Canadian Oil and Hazardous Material Pollution Contingency Plan For The Great Lakes Region". Provincial approval for an amended version of the International Contingency Plan was given in January, 1973.

To ensure that the complete resources available within the Provincial Government departments could be made available to cope with major emergency situations, it was decided to solicit more complete participation. The "Interministerial Task Force on Contingency Planning" was therefore established in June, 1971 for the purpose of reviewing and updating the Province of Ontario Contingency Plan and to ensure that each Provincial ministry involved is aware of its responsibilities upon activation of the contingency plan. The Provincial ministries represented on the Task Force are the Ministries of: Environment, Natural Resources, Transportation and Communications, Health, Solicitor General, and Consumer and Commercial Relations. Environment Canada and industry (PACE*) are also represented. Since its inception, the Ministry of the Environment has provided the Chairman for the Task Force.

STATUS OF THE PROVINCE OF ONTARIO CONTINGENCY PLAN

As it now stands, the Provincial plan outlines a framework for spill discovery and reporting, and for the coordination of available manpower, equipment, and material resources to control and clean up major spills. As previously noted, the plan was developed within the OWRC and, consequently, is limited to spills which may affect the surface or ground waters of the Province.

The Provincial plan was designed to operate in cooperation with other Provincial, Municipal, and Federal Government agencies, and was developed to be compatible with other government and industrial contingency plans. Responsibilities of the involved agencies are contained and outlined in this plan.

The response structure outlined in the contingency plan requires the establishment of Regional Response Teams throughout the Province. A Regional Response Team consists of key Provincial and Federal representatives who are most likely to be directly involved or are particularly interested in the prompt and proper response to major spill incidents and who are able to make a contribution for the containment and clean-up of such spills. The team presents an expertise pool at the regional level who collectively represent government or regulatory programs which deal with, pertain to, potentially affect or involve the natural environment.

* Petroleum Association for Conservation of the Environment.

The main function of a Regional Response Team is:

1. to provide an effective communications link during a major spill incident with the party responsible for the incident (if known), the party or parties retained to contain and clean-up the spill, and the government or regulatory agencies who have a vital interest in the particular spill incident,

2. to ensure that all necessary information is made available to the Response Team Coordinator during a major spill incident so that the most effective courses of action can be formulated for combating such spills,

3. to maintain an updated equipment directory, which includes an updated contact list, covering the particular area for which the team is responsible. This directory includes information from the government and private sector.

Since the publication of the 1971 Provincial plan two Regional Response Teams have been established. There are the Lambton County Regional Response Team and the Ottawa - Carleton Regional Response Team. Similar teams are presently being established for the following areas or centres:

Thunder Bay
Sault Ste. Marie
Sudbury
Windsor
London
Hamilton and Niagara Peninsula
Toronto
Kingston and Cornwall.

The terms of reference of these teams do not limit their response to the political boundaries implied by the preceding names.

I have briefly covered the history of the Provincial plan and made reference to when the Federal and International plans apply. These three plans come into play in the event of near catastrophic spill incidents. A great majority of all spills, however, involve incidents of a much lesser magnitude. Industry and Municipal contingency plans, and contingency plans of industry cooperatives are designed primarily to cope with the less than major spill incidents. As I have pointed out before, these

local plans of preparedness have proven to be very effective in dealing with smaller spills. The Provincial plan depends to a large degree on the existence and effectiveness of plans at the local level. You recognize, I am sure, that even an initially minor spill if left unattended may turn into an incident of significant proportion.

It has become necessary since the publication of the Provincial Plan in 1971 to redefine the magnitude of spills to incorporate more fully the enlarged role of the Ministry of the Environment. At present, under the Province of Ontario Contingency Plan the magnitude of spills are defined as follows:

I Minor Spill

A minor spill is a spill incident of oil or other hazardous material -

1. of such magnitude in which the party responsible for the spill can, utilizing his own resources, undertake the necessary measures to control, contain and clean up the material spilled; and

2. of such a magnitude as to have no significant effects on fish and wildlife; and

3. not likely to significantly affect or interfere with any private, municipal, industrial or other water supply; and

4. of such a nature as not to generate public concern.

II Moderate Spill

A moderate spill is a spill incident of oil or other hazardous material -

1. of such magnitude in which the resources under a local or cooperative contingency plan are required to effectively contain and clean up the material spilled; or

2. of a volume or type likely to present a significant hazard to fish or wildlife; or

3. of such a nature as to result, or likely to result, in only local adverse effects on, or interference with, any private, municipal, industrial, institutional or other water supply; or

4. of such a nature as to generate public concern in the vicinity of the spill incident.

III Major Spill

A major spill is a spill incident of oil or other hazardous material -

1. of any magnitude requiring resources in addition to those available under a local contingency plan, or a spill which gets out of control when action is being taken under a local contingency plan; or

2. which adversely affects or interferes with or will adversely affect or interfere with private, municipal, industrial, institutional or other water supply or water supply systems other than in the immediate area of the spill; or

3. of such a nature as to present a hazard to human health; or

4. of such a nature as to have or most likely to have serious adverse effects on fish or wildlife over a wide area; or

5. of such a nature as to generate or likely to generate considerable public concern.

IMPLEMENTATION OF THE PROVINCE OF ONTARIO CONTINGENCY PLAN IN WHOLE OR IN PART WOULD BECOME EFFECTIVE UNDER THE CONDITIONS COVERED UNDER MAJOR SPILLS.

THE ROLE OF THE ONTARIO MINISTRY OF THE ENVIRONMENT IN SPILL INCIDENTS

Irrespective of the cause of spills, and irrespective of all other reporting requirements, any person from whose control any potentially hazardous material escapes which may adversely affect the natural environment, is responsible for reporting the loss of such a product as soon as possible to the Ministry of the Environment. Failure to comply with these requirements is an offence under the Water Resources and the Environmental Protection Acts and subject

to a maximum fine of $5,000. Recent amendments to the legislation make the party from whose control a deleterious substance escapes responsible for repairing any environmental damage which may result.

With the preceding as legislative background, the primary role of the Ministry of the Environment is to ensure that prompt containment (where possible) and clean-up activities are taking place should a spill occur. When an officer of the Ministry appears at a spill site, depends on a number of factors. There are many spills of a purely minor nature. Most of these spills are promptly cleaned-up and do nct require our immediate presence. Very often the spills are being reported to us while clean-up is in progress or has already been effected. An inspection of the spill site will be made by Ministry staff in such instances as soon as possible during regular working hours.

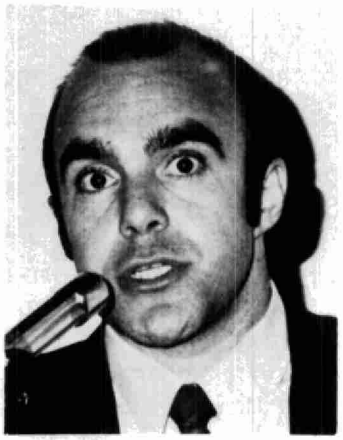
About 20% of all spills may be classified as moderate spills. These spills involve such general incidents as road accidents involving tank trucks, pesticide and herbicide spills, most well contamination cases (other than those attributable to bacteriological contamination), pipeline breaks and the smaller freight train derailments involving spills of deleterious substances. When an officer of the Ministry of the Environment appears at the site of moderate spills very often depends on the nature of the spill, and on what actions are being undertaken at the time. We will appear as soon as possible in any event. Should we feel, however, that our presence will result in a more effective response to a spill incident, we may shift our priorities and inspect such an incident sooner than would otherwise be warranted. Little can be gained for instance by dispatching a Ministry representative at 2:00 AM Sunday morning to a well contamination incident which is the result of a petroleum product spill that may have taken place days or weeks before.

Major spills as defined previously occur very rarely. These spills include such incidents as serious freight train derailments, ship collisions, some pipeline breaks and so on. In such events Ministry of the Environment staff will be dispatched as soon as we find out about the spill. As noted earlier, the Ontario Contingency Plan would be implemented under these conditions. As with minor or moderate spills, the primary function for the Ministry of the Environment representative is to ensure prompt and proper protection against damage to the environment or to minimize such damage.

Occasionally the nature of a spill incident is such that counter measures have to be taken immediately, and the task of establishing responsible parties or other matters is incomplete. In such instances the Ministry of the Environment may initially assume command for the purposes of effecting prompt action. The Welland train derailment of December 1972, which resulted in the loss of approximately 1200 tons of concentrated sulphuric acid, is an example of such involvement on our part. Containment, clean-up and site restoration costs in such cases are borne by the responsible party.

On occasion we become involved in what has been classified as a "mystery spill": those reported oil slicks or other contamination incidents which present a significant hazard to the natural environment and should be dealt with promptly, and which cannot be tracked to a source to establish responsibility for the incident. In such instances we will effect the necessary clean-up operation with the full intent of recovering the expenses incurred in the event that responsibility can later be established. I did say at the beginning of my presentation that the Ministry of the Environment is not in the spill clean-up business. What I just said about mystery spills does not change that statement.

As custodians of Ontario's natural environment, the Ministry of the Environment is actively involved in persuading those who manufacture, transport or store potentially hazardous substances to develop their own plans of preparedness for the event of spillages. The Ministry endeavours to ensure that those responsible for spills of deleterious substances effect prompt counter-measures to minimize damage to the natural environment.



D. C. Cook

POLLUTION ABATEMENT THROUGH BY-PRODUCT DEVELOPMENT

BY

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LABATT BREWERIES OF CANADA LIMITED,
LONDON, ONTARIO



J. H. Linton

and

DR. J. H. LINTON,
DIRECTOR OF BIOTECHNICAL SERVICES,
MIRA-LABS DIVISION,
THE OGILVIE FLOUR MILLS CO. LTD.,
LONDON, ONTARIO.

PART I

The philosophy taken by Labatt Breweries of Canada is Waste Management and Pollution Control can be good business and money can either be made or saved. The main approach is to do as much in-plant product and by-product recovery as economically as possible. In all cases the remaining effluents are discharged to municipal sewer systems and surcharges are paid to the city when required. In many cases new technology must be developed to recover the by-products and dispose of them.

One of the companies owned by John Labatt Limited is a feed company called Miracle Feeds. It was felt that most of the by-products from the Brewery could be collected and marketed as animal feed. Miracle Feeds has extensive research facilities including an Experimental Farm and these facilities were used to check the nutrient value of the by-products and to determine the best method of marketing them. They are currently working on new methods of marketing the by-products from the Brewery as well as those from other food processing type plants.

The first step in Pollution Control at the Brewery was to carry out a detailed in-plant survey of the sources of pollution being discharged to the city sewers. This survey was carried out in

Labatt's London Brewery. The main sources of the high B.O.D. and S.S. discharged from the Brewery were determined and methods of collecting and disposing of these by-products were investigated. The B.O.D. from a typical brewery (without controls) would be about 1200 ppm and the S.S. would be about 800 ppm.

The main raw material used in brewing is barley malt. At the malthouse the barley is germinated to activate various enzymes which will later help to break down the barley starch and proteins to less complex compounds which are readily soluble in water during the brewing process. Following germination, the malted barley is dried and shipped to the Brewery.

At the Brewery the malt is crushed in a special mill which separates the outer husk from the inner extract yielding material. The inner material is finely ground to aid its solution in water, while the husk is left mainly intact so that it may aid as a filter material when the extract solution is collected.

The ground malt from the mill is now mixed with 120°F water in a vessel called the mash mixer. The object of this "mashing" process is to make the extract soluble with the help of the previously activated enzymes. This is achieved by intermittent stirring and heating for defined periods from 120°F to 155°F. A soluble, fermentable extract is thus obtained. At the end of the mashing process the "mash" is heated to 170°F to inactivate the enzymes, following which it is transferred to a giant strainer called the Lauter Tun.

The Lauter Tun has a perforated false bottom upon which the mash is evenly distributed. The solid particles settle out onto the false bottom to form a filter bed. The liquid extract (called "wort") is then filtered off into the brewkettle leaving the insoluble portion of the grain behind.

The insoluble portion of the grain, or spent brewers grains, are then removed from the Lauter Tun into a spent grains tank. During the removal of the grains and the washing out of the tank, the Lauter Tun drain and rinse are sent to the sewer. These streams contain about 17% of the B.O.D. and 10% of the Suspended Solids being discharged from the Brewery.

The spent brewers grains are the main by-product from the Brewery and are generally sold as cattle feed. There are about 50,000 pounds of wet spent grains produced per 1,000 barrels of beer produced. (1 barrel of beer = 25 Imperial gallons)

In 1952 the decision was made to dry the spent grains produced in the London plant. Previously, they had been sold wet. At that time there was a poor market for wet grain, there were scheduling problems removing it from the Brewery and there was trouble with the leakage from the trucks onto the road. One major problem with marketing spent grains is the supply is out of phase with the demand. Most of the beer, and thus the spent grains, is produced

during the summer when the cattle are left outside to graze and the production rate in the winter is low when the cattle are indoors and require feed.

In the late 1960's complaints were received from the Air Management Branch about the operations of the drier. The drier used heavy oil so there was some SO_2 from the oil as well as odours and particulates from the grain. The grain was pressed before it was put into the drier to reduce the moisture content from about 75% to 68%. The liquid, called the pressed grain liquor, was sewered and it contributed about 7% of the B.O.D. and S.S. being discharged from the Brewery.

The installation of a fume incinerator and conversion of the drier to natural gas was investigated. It was determined that the fume incinerator would cost $100,000 to install and the conversion of the drier would cost $20,000. The cost of the natural gas for drying the spent grains would be $30,000 per year and the cost of the natural gas for the fume incinerator would be about $50,000. The operating costs for the drier would therefore be in excess of $100,000 per year.

Work was carried out to determine if the grain could be marketed wet at a suitable price. Research indicated that this approach was possible providing a sophisticated marketing method was used. A good cheap method of off-site storage for the grain had to be developed and trucks that would not leak had to be purchased. Starting in the fall of 1971, some of the spent grain was taken out of the London plant and sold in its wet form. Since the fall of 1972, all the spent grains have been sold wet. The capital costs incurred were about $20,000 rather than $120,000, the air pollution problem was solved, the high operating costs of drying were eliminated and the B.O.D. and S.S. of the sewers was reduced by about 10%.

The wort which is strained into the brewkettle from the Lauter Tun is boiled with hops to evaporate some of the water and concentrate the extract to dissolve the bitter substances of the hops and to bring about coagulation and precipitation of undesirable solids. The hops are added at intervals throughout the boiling period. The wort is then pumped from the brewkettle, through the hop separator into the hot wort tank.

The spent hops which are removed from the hop separator are added to the spent grains. At one time it was believed that the hops would make the spent grains very bitter and unpalatable to the cattle. Tests were carried out that indicated that this was not the case and there have been no problems with the spent grains due to the hops. The addition of the hops to the spent grains gives some extra revenue and it does not have to be disposed of at a cost. It will reduce the B.O.D. by about 3% and the S.S. by about 9% over sewering them if this is permitted.

A solid substance known as trub settles to the bottom of the hot

wort tank. The trub is mainly a protein which was formed during the boiling in the brewkettle. The trub contains about 26% of the B.O.D. and 14% of the S.S. It was also believed that the trub could not be added to the spent grains because it was bitter and would cause palatability problems. Tests were carried out which indicated this was not the case and therefore, the trub was added to the grains. There has since been no palatability problems due to the addition of trub.

Once the trub has settled out of the wort, the wort is cooled and pumped to a fermenting vessel. Yeast is added to the wort and it is fermented into beer. During the fermentation process, alcohol, CO_2 and more yeast are produced. For each pound of yeast that is added to fermenting, about 6 pounds of yeast are removed. Part of this is recovered and used for further fermentations but the rest is excess. About 6,000 pounds of excess wet yeast are produced per 1,000 bbls. of beer. This yeast contributes about 30% of the B.O.D. and S.S. to the total effluent if sewered.

The yeast as it is collected, is a live cell and it is not suitable as an animal feed in this form. The yeast must be killed before it can be used as a feed and the best method is to heat it to 150°F by injecting steam into it. Once the yeast is killed, it can be added to the spent grains or used as a liquid feed. Yeast contains a high concentration of protein, vitamins and minerals and is therefore a very valuable food product.

The addition of the yeast and trub to the spent grains does solve the disposal problem but it does not give the full value for the protein in these products. There is a growing world wide shortage of protein and the value should increase in the next few years. This value can be obtained by drying trub and yeast but the operating and capital costs are fairly high. Further research work is being carried out to determine if these products can be sold wet for their protein rather than dry.

Once the beer is taken from fermenting, it goes to primary ageing. In primary ageing, a small amount of yeast and protein is settled out. The beer is then sent to primary filtration where the beer is filtered using diatomaceous earth. The beer is then sent to secondary ageing. After secondary ageing, the beer is again filtered and then is either kegged or bottled for sale. The wastes from the filters contribute about 4% of the B.O.D. and 20% of the S.S. to the total effluent. Preliminary investigations revealed that spent filter cake was not suitable for addition to spent grains because of low nutritive value and high silica levels. Current research efforts are being directed toward elucidating an effective replacement for diatomaceous earth which could also serve as a nutrient source for livestock, and thereby permit addition to the spent grains.

The current program with grain being sold wet with the hops, trub and yeast added has proven quite successful to date. The total B.O.D. and S.S. from a brewery using this approach will be

significantly reduced. There have been some problems with the moisture content of the grain which should be maintained less than 80%. Further experimental work is being carried out in better utilization of the feeds. The second part of this paper will describe the feeding trials and the marketing programs.

PART II

Introduction

The foregoing (Part I) presentation described the brewing process, sources of pollutants and some of the alternatives which were considered to reduce effluent load.

In this presentation, I will describe some of the key developments which have led to the utilization of wet Brewery by-products as components of effective livestock feeding programs and significant reductions in Brewery environmental pollutants.

Nutritive Evaluation

The detailed analytical composition of the various waste commodities was determined through systematic sampling. A brief summary of analytical data is displayed in Table II.

The analytical data was then used to formulate rations for the various classes of domestic livestock which would meet their nutritive requirements for growth and production. Numerous feeding trials were conducted and the productive performance of the animals fed the various ration formulations were evaluated.

The conclusions drawn from these animal feeding trials were as follows:

1. The optimal moisture content of Brewery waste mixtures is between 75% and 80%. Higher moisture results in free water loss and difficult storage and handling characteristics. Lower moisture contents make compaction difficult which leads to oxidative degradation.

2. An adjustment period of about three weeks is required in changing ruminant rations to Brewery by-products. More rapid changeover results in digestive upset.

3. Rations containing wet brewers grain: yeast mixtures provided adequate protein to meet the nutritive requirements of ruminants, thus eliminating the need to supplement with other high cost protein sources.

4. Incorporation of spent hops with spent grains at levels up to 10% had no deleterious effect on voluntary intake of wet spent grain by dairy steers.

5. The addition of attenuated (steam killed) spent yeast slurry with spent grains in the ratio of 1:6 (wet basis) resulted in improved voluntary feed intake, rate of gain and feed efficiency of beef steers.

6. The carcass characteristics and quality of meat obtained from animals fed Brewery by-products are excellent.

7. Rations containing wet brewers grain yeast mixtures enhanced milk yield of Holstein dairy cows and reduced feed cost per 100 lb. of milk produced when compared with a traditional feeding program.

8. The feeding of Brewery by-products to dairy cows had no deleterious effect on the quality of milk produced in terms of flavour, chemical composition or bacteria content.

9. Ruminant liquid feed supplements utilizing liquid Brewery waste and molasses were found to be palatable and supported productive performance equal to other commercially available supplements.

10. Swine fed liquid feeds based on Brewery waste performed as well as those fed conventional feeds and yielded carcasses of equivalent score.

The overall assessment of these nutritive evaluation studies was that wet Brewery by-products can serve as an effective, economical nutrient source for various types of domestic livestock.

Systems Development

To effectively commercialize the utilization of wet Brewery by-products as a livestock feed, various specific systems had to be developed to ensure compliance with environmental regulations and market requirements.

(a) In-plant collection, processing and loading systems:

Spent hops and trub are collected and evenly distributed into the primary spent grain tank below the Lauter Tun. This mixture of spent grains, trub and hops is then pumped to secondary storage tanks of two - five brew capacity. Spent yeast is collected from the fermenting and ageing areas and pumped to separate storage tanks. Yeast cells are inactivated by steam injection when pumped from storage to loading area. The killed yeast is then metered into load-out incline auger system and thereby mixed with grains, hops and trub. Excess

spent yeast is delivered to tank trucks for liquid feed supplement use or further processing to yield hydrolysates.

(b) Transportation and handling systems:

To eliminate drip loss in transit, special truck boxes were designed with rubber sealed end gates and turn buckle clamps.

Farm storage units of various types have been designed to meet the particular needs of individual farms. Some are constructed of concrete, others of wood, but all are sized to accommodate a minimum of 8 tons (1/2 load). An automatic unloader system (Figure I) has been designed and constructed at our Research Farm which eliminates manual labour and surface spoilage.

(c) Product quality control systems:

Samples are collected periodically as by-products are loaded at the plants to ensure maintenance of product specifications for moisture, protein, excess sugars and yeast viability. In addition, each load is visibly scrutinized for abnormality by the Brewery operator and delivery man.

(d) Long term storage systems:

Ensilage systems have been developed to ensure the continuous supply of product during plant holidays and shut downs. Furthermore, this permits a leveling of supply through delivery of excess to storage during peak production (summer) and withdrawal as required during lower production periods (winter).

The ensiling system involves filling horizontal pit silos with wet Brewery by-products (75% moisture) and tightly sealing with polyethylene sheeting. The addition of a small amount of organic acid has been found to enhance keeping quality and subsequent trough life.

The reduction of bulk density by incorporation of other dry feed ingredients (i.e. corn, barley, etc.) facilitates long term storage in conventional vertical farm silos.

Mira-Mash Customer Service

(a) Farm feed ingredient analysis service:

Miracle service men collect representative samples of all available on-farm feed ingredients and submit these to the central feed test lab for analysis. Information is also submitted on:

- Farm feed inventories.
- Number, breed and class of livestock to be fed.
- Previous average milk production or rate of gain.
- Other (type of facility, handling systems, herd health, etc.).

(b) Customized supplements:

Laboratory analytical results revealed extreme variations in nutritive value of on-farm ingredients which necessitated the development of various types of premixes and supplements to meet the particular requirements of each livestock operation. A series of macro-premixes have been designed to be mixed with home grown grains, while various supplements were designed for top-dressing on the feed. The deficit in mineral and vitamin requirements of the particular livestock operation will indicate the optimal supplement specifications. Peculiar area or farm deficiency conditions (i.e. Mg in some Southwestern Ontario farms) are provided for on a customized basis.

(c) Computerized least-cost formulation service:

Feed is the major cost factor in any livestock production operation. Improper formulation results in poor productivity, poor efficiency and poor returns. In order to "optimize" a feeding program, it must be "balanced" to provide the correct proportion of all nutrients essential to meet the particular requirements for maintenance, growth, gestation and/or lactation at minimal cost. A schematic illustration of an imbalanced ration is displayed in Figure 2.

A preliminary market survey revealed that many traditional feeding programs were imbalanced and livestock producers involved lacked the capability to make adjustments based on analytical data provided. Thus, a computer system was developed which would provide a properly balanced least-cost feeding program based on the analytical and inventory data obtained from each farm.

(d) Technical service:

The technical support staff currently involved in the utilization of wet Brewery by-products as livestock feed include three Ph.D. Nutritionists, one Veterinarian, one Economics and MBA graduate and numerous field service men with Agriculture Diplomas or equivalent experience.

Each field service representative is responsible for on-farm sampling, supplement distribution and program description within a designated area. The Nutritionists handle laboratory operations, computer linear programs, technical meetings and

research, while the Veterinarian provides inputs re: herd health and sanitation. In addition, each region maintains a distribution co-ordinator who assures an orderly Brewery pick-up and farm delivery system.

The Miracle Program is briefly summarized in Figure 3.

Current Status and Future Objectives

Brewery by-products are currently being marketed in wet form from all Labatt operations across Canada. Certain plants, however, do have drier installations which meet Air Management specifications, which will be used as required to alleviate summer production problems. In future, more on-farm silo storage capacity may eliminate the use of driers completely.

A major future objective for Miracle Agriculture products and services is to assist other industries in the disposal of by-products which can serve as nutrient sources for domestic livestock production.

TABLE I

SOURCES OF POLLUTANTS FROM A BREWERY

SOURCE	B.O.D. LBS/1000 BBLS. OF PRODUCT	B.O.D. %	S.S. LBS/1000 BBLS. OF PRODUCT	S.S. %
Yeast	960	30	660	30
Trub	830	26	320	14
Hops	100	3	200	9
Pressed Grain Liquor	220	7	130	6
Lauter Tun Drain and Rinse	540	17	220	10
Filter Effluent	130	4	410	19
Bottling	310	10	170	8
Miscellaneous	110	3	90	4
TOTAL	3,200	100	2,200	100

1 bbl. of beer = 25 I. Gals.

TABLE II

ANALYTICAL COMPOSITION OF VARIOUS BREWERY BY-PRODUCTS

	SPENT GRAIN	SPENT YEAST	TRUB
DRY MATTER %	20.0	11.5	16.8
CRUDE PROTEIN %	6.13	4.8	5.8
FAT %	1.77	0.13	0.25
FIBRE %	2.98	0.35	0.20
CALCIUM %	0.08	0.015	0.047
PHOSPHORUS %	0.12	0.17	0.043

Figure 1

BREWING SCHEMATIC

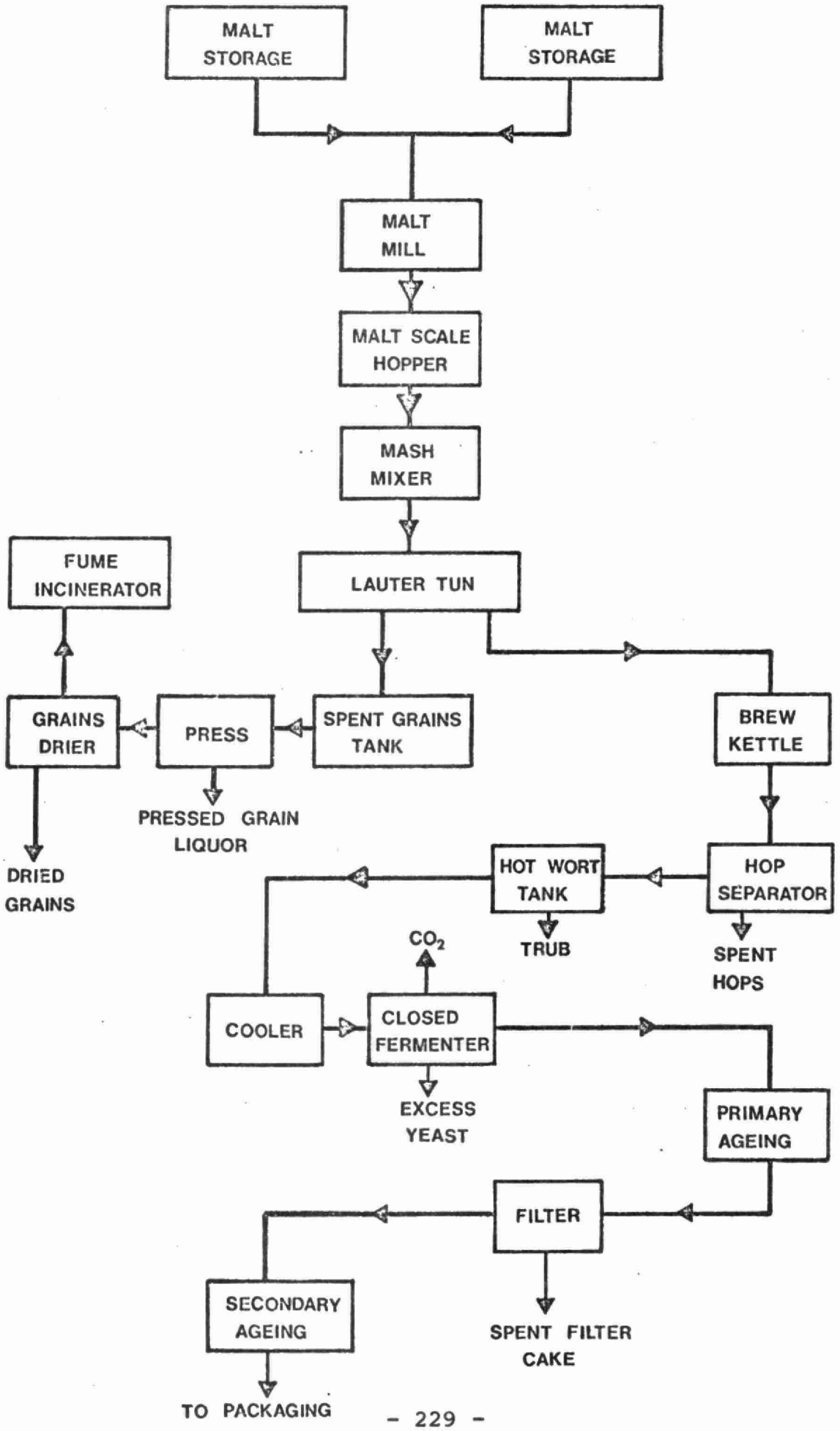


Figure 2

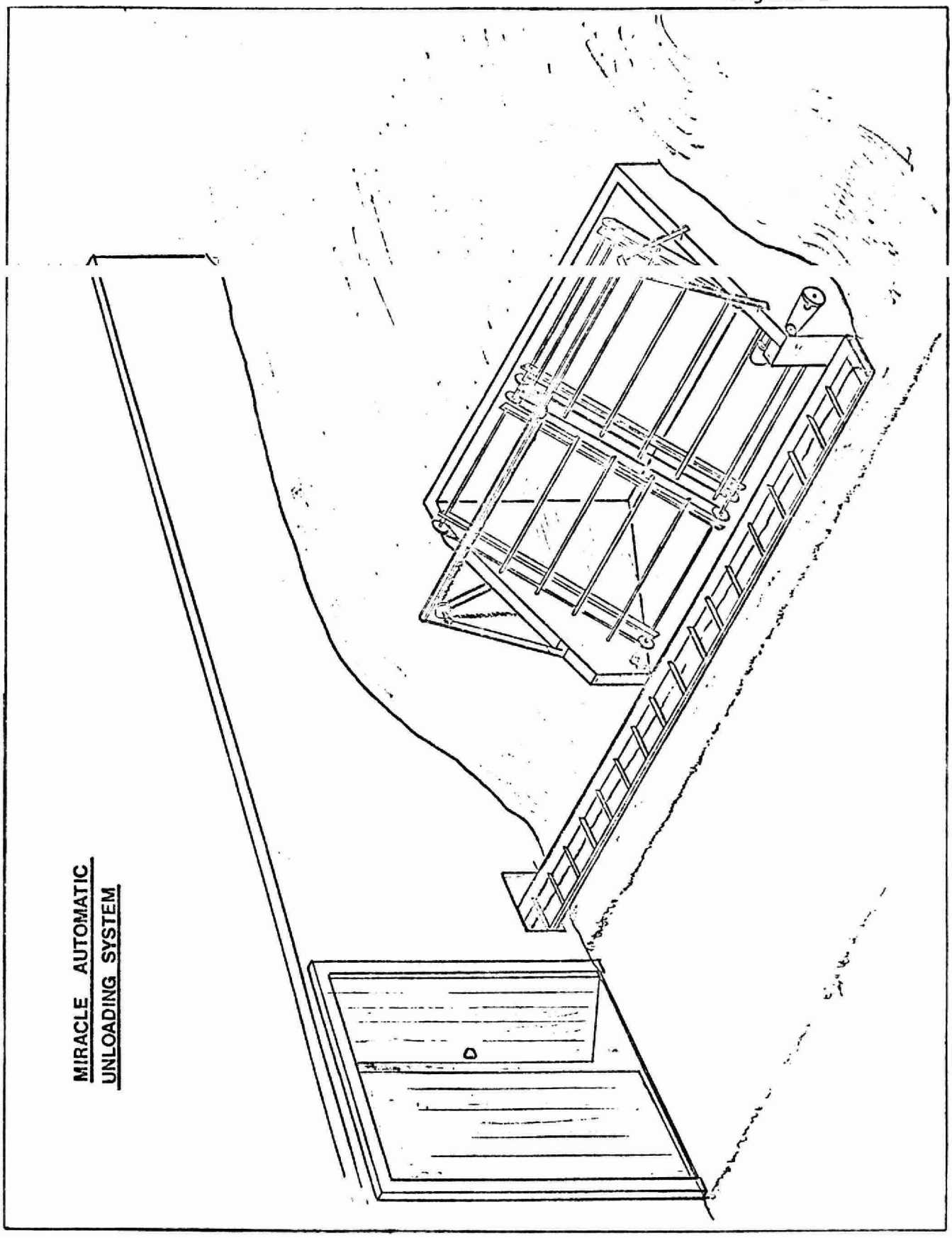
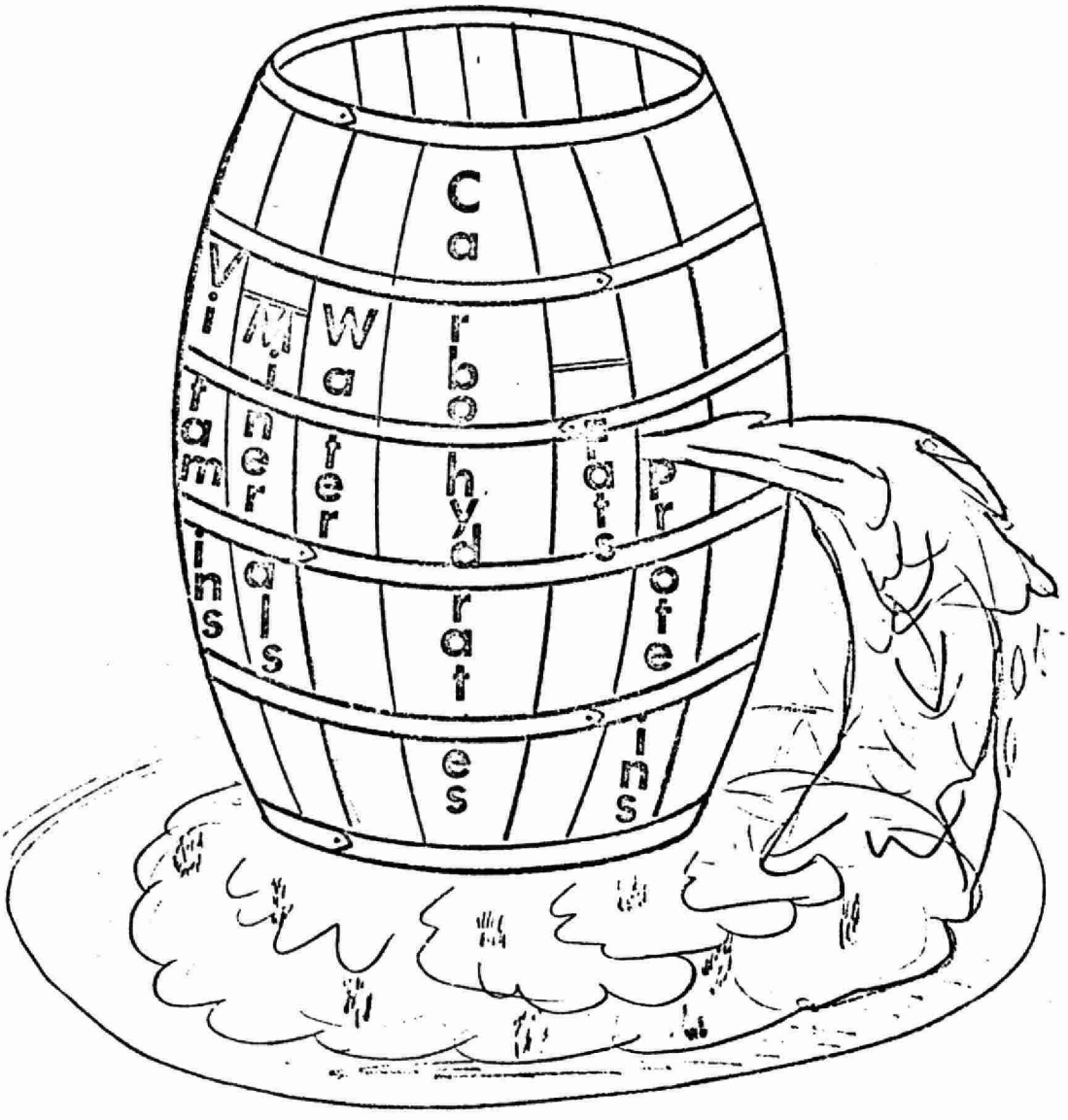
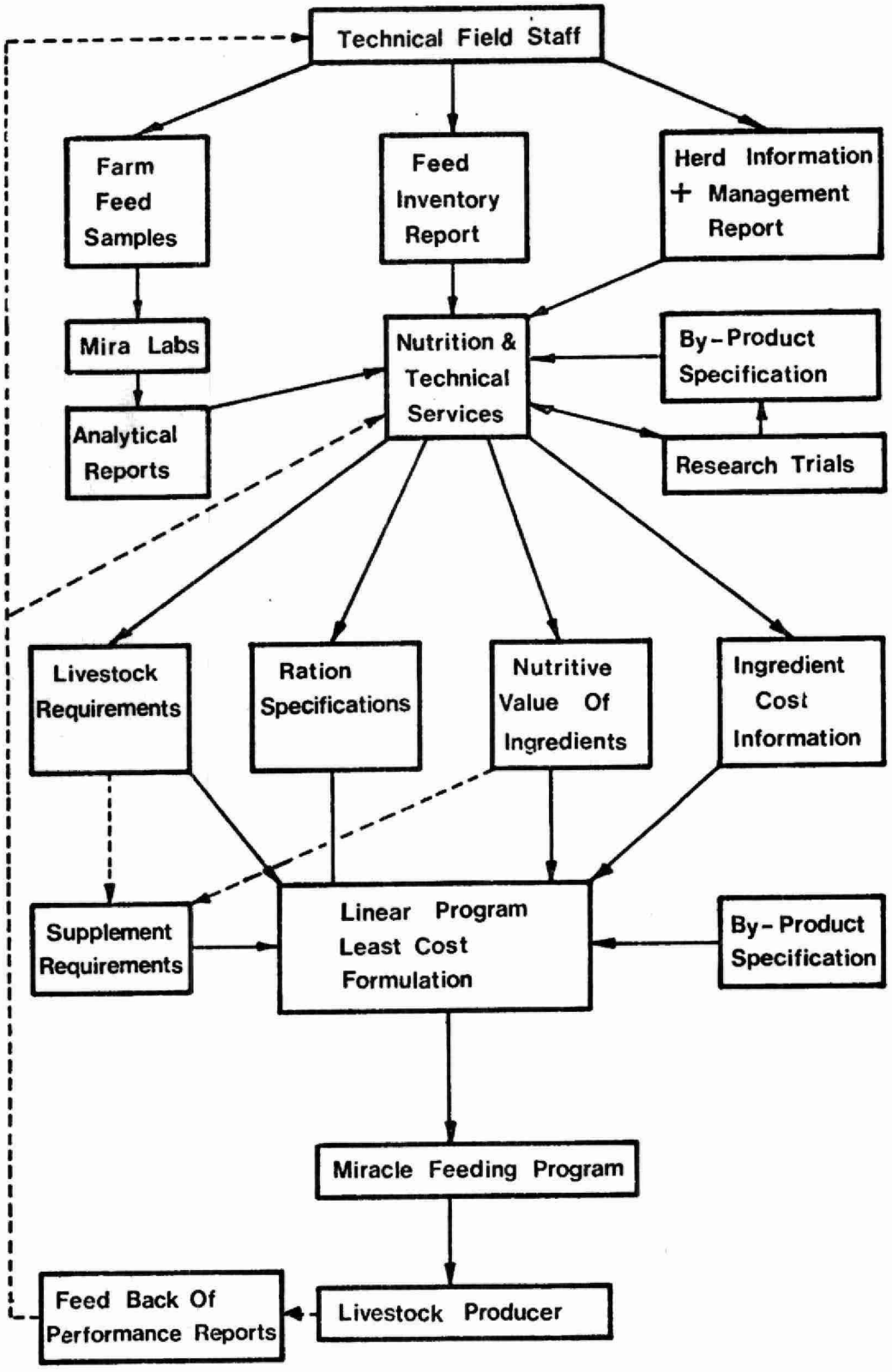


Figure 3



MIRA MASH PROGRAM



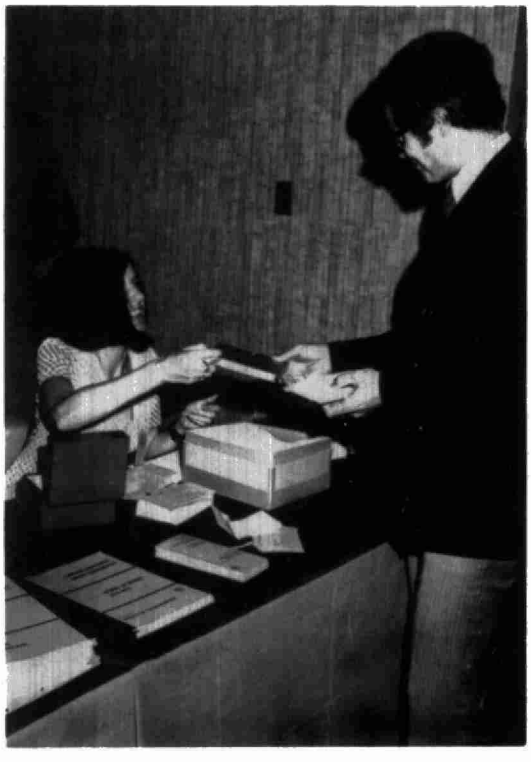


... guest speaker at the luncheon on Monday, June 18 - Mr. Everett Biggs, Deputy Minister of the Environment



Delegates during one of the technical sessions in the International Room of the Skyline Hotel

...



... at the Conference registration desk in the Main Lobby



... The George Frank Orchestra entertaining delegates and guests at the dance in the International Room of the Skyline

Delegates and guests enjoying the banquet and dance

...





Introducing the featured speaker at the banquet, Mr. Art Duncan, on the subject of "Humour and Conservation". Mr. Duncan was formerly Director of Public Relations for Worldwide Bata Industries

...





CHAIRMAN - SESSION V,
DR. R. WHITEHEAD,
MANAGER AND PRINCIPAL CHEMIST,
JAMES F. MacLAREN LTD.,
LONDON, ONTARIO.



J. D. Heaman

THE SOLID WASTE SCENE IN 1973

BY

J. D. HEAMAN,
EXECUTIVE OFFICER,
SOLID WASTE TASK FORCE,
MINISTRY OF THE ENVIRONMENT,
TORONTO.

By this time Murphy's Law has grown over-extended; possibly a little bit akin to Newfoundland jokes, so I shall originate a new series known as Blimp's Law. It is about time that the jolly Colonel is resurrected. So Blimp's Law states that public demand for services constantly exceeds the capability of Government to supply. Mind you, the Civil Service responds nobly as the Budget attests. To return to the Law, this is nowhere more true than in problems associated with waste management. It was only during 1966 that the first engineer, or indeed any individual, was employed full time by the Provincial Government in matters directly associated with, so called, solid waste management. During the intervening period until today, that one engineer has multiplied to a total staff within the Waste Management Branch and associated activities, of forty-seven, and with a direct budget of $2,283,600. Quite an increase. And the staff appears to be merely keeping up with day to day requirements, while attempting to devote some attention to forward planning.

To what does this translate in activity? Possibly this is most simply illustrated with the observation that a year or so ago it was considered novel information for any technical paper on the subject of waste management to define the difference between sanitary landfill and an open dump. If I were tempted to do this today, to this audience, the best I could expect would be polite yawns. The art of waste management has advanced rapidly during these seven years. From the Municipal point of view, we can even take comfort that practice has advanced considerably. Early in 1968, with the co-operation of the local health units, I launched a survey to gain some idea of the number and types of disposal sites in Ontario. I might say, in passing, that, at that time, reliable statistics on waste management were almost non-existent and, regrettably, the situation is not much better today. Nevertheless, at that time, we obtained reports on 983 sites, of which 57% were open dump, 20% modified landfill and 17% sanitary landfill. 2% of the number were incinerators and 4% were undisclosed. Under the values of that day, 47% were reported as satisfactory operation, and 30% unsatisfactory, and 57% reported open burning. Although I have been unable to obtain comparable figures for the present situation, I am satisfied that it is considerably improved.

You will observe that I have been speaking entirely of disposal sites and their condition, with emphasis on landfill. This was precisely our concern at that time. Disposal methods generally were crude, with many disgusting and undesirable practices. Our primary concern was to guide the Municipalities towards improved practices, which would be aesthetically acceptable, and environmentally sound. There has been substantial progress, and yet many of the public are dissatisfied and pressing for more and more sophistication and new approaches. Progress and improvements are fine, and much to be desired. Nevertheless, there appears no vital necessity to rush precipitously away from tested methods which, indeed, themselves were new and novel only a half a decade ago. Considering that sanitary landfill was a relatively new approach a few years back, it is disturbing to see it derided as archaic today. I emphasis with all the persuasion I can command that properly designed and operated sanitary landfill is a safe, reliable and environmentally acceptable method for the disposal of general wastes. After all, how else but by dumping on the land have most wastes been handled since the dawn of history? In spite of this we are hard pressed in Canada

to find anything that has been around more than 100 years, with the exception of Laurentian granite. It is also the disposal method which requires the lowest expenditure in dollars for all direct activities of disposal.

The orderly and safe disposal of pathological, or as preferably described, anatomical waste, is another special problem with interesting complexities. A study group has evaluated the issues and determined the direction for enquiry. From this a detailed study has been commissioned and, from the report which is expected momentarily, it is hoped that the way will be clear for concerted action on this unpleasant, but necessary, aspect of modern living.

A further problem is the disposal of sludge from sewage treatment plants. The removal of a contaminant from one element of the environment necessitates disposal elsewhere and, as you all know, the prevalent method is disposal onto land. This is receiving extensive study and a number of treatments are being evaluated. In the meantime, Regulation 217/73 has been made under the Environmental Protection Act.

A further Regulation has been issued which controls the subterranean disposal of liquid industrial wastes. On the subject of industrial wastes generally, the Ministry has been successful and effective in promoting the development of substantial facilities, which for the first time in Ontario provide for the orderly and nuisance-free disposal of liquid industrial wastes. These include the facility owned by Canadian Industries Limited and operated by its subsidiary, Goodfellow Enterprises, and situated on Government-owned property in Mississauga. An ancillary operation is located near Sarnia. Another substantial development is the liquid waste incinerator in Hamilton, operated by Interflow Systems Limited. The facilities either available now, or in the design stage, will provide for incineration of liquid wastes, including halogen bearing compounds, and neutralization of acids and alkalis with separation of precipitated solids.

In summary with respect to disposal, I am of the view that all of the areas of concern have either been effectively evaluated or working solutions are in being, with two significant exceptions. These are agricultural wastes and sewage sludge. In both cases, expedients are providing alleviation, but truly effective solutions are a long way from adoption. It appears clear

that disposal should be onto the land, but existing processing practices and agricultural problems appear to mitigate against an adequate solution.

In making these statements, I hope that they will not be construed as indicating that we have any reason to rest on our laurels and be content. Much of what is being done today is, indeed, effective in that essential needs are being supplied, using methods which are bearable. Nevertheless, there are many, and I am one, who believe that entirely new philosophies will have to be accepted, and practices developed in harmony with these philosophies, if the quality of our environment is to be maintained. Some imaginative work is, of course, proceeding along these lines, and as an example I can mention the Canwel Project, which as many of you know stands for Canadian Water Energy Loop. This, essentially, provides for an almost totally enclosed system for a group of residences, whereby water is recycled and most solid wastes are disposed of on site.

The subject of litter is one which is inextricably part of the waste management scene. I think that there has probably been more heat generated, and more printer's ink employed, on the subject than has occurred with any other in the waste management field. The fall-out has extended far and wide, and has resulted in many additional activities. One of these is the Solid Waste Task Force, and I shall deal with this in more detail later. Sparked by voluminous discussion and considerable action by many local groups, an investigation of the various aspects of litter and littering was launched by the Ontario Government during 1970. At this time a Group known as the Littering Control Council of Ontario was formed by the Minister of Energy and Resources Management. It consisted largely of members representing industry and commerce, and groups concerned with environmental quality. The sessions were most interesting. In the beginning there was almost some doubt as to whether all of the members would be on speaking terms, but towards the end it was remarkable to see how discussion and exchange of ideas mellowed the mix. Finally the point was reached where most, if indeed not all, accepted that there might, indeed, be some middle ground, even while continuing to fight vigorously for his own point of view. I am satisfied that we were breaking new ground, although it is patently evident that no sweeping agreement was reached. Nevertheless, a basis for mutual confidence and respect was laid; and much of what is proceeding today towards the resolution of conflict in environmental matters, associated with waste management, stems from this beginning. The

proceedings of the Council have been printed and are available, so there is no point in my going further into the details.

One rationale states that littering is a "people" problem, and that it is not a matter for waste management, but can only be corrected through a re-alignment of people's values, brought about by a massive education effort. Another opinion states that littering is the logical outgrowth of careless, thriftless habits generated by a society addicted to throw-away attitudes. It is held that this posture is fueled by the inexorable hunger for more and more production, maintained by industries and merchants associated with packaging, and consumer "appetite" goods, such as beverages, candy and tobacco.

From the simplistic point of view of waste management, the problem is negligible. Litter, though highly visual, does not represent a significant tonnage. Packaging, whether excessive or not, is not difficult to handle once it enters the collection and disposal system. Our situation is that we are not faced with decisions with respect to waste management policies, but the need for those which are social and political, and this leads me to the Solid Waste Task Force.

The rallying cry of several diverse associated interests has been "ban the bottle". This is an over-simplification resulting from concern caused by litter, increasing waste generation, increasing pollution of the three elements of the environment, rising costs of waste disposal, concern over dwindling energy sources, and depletion of non-renewable resources. All of this makes a very imposing array, and much of the fury has been directed towards the beverage industry and particularly the non-returnable bottle. There is, of course, the non-returnable can, and a number of other articles, even including the non-returnable candy-wrapper and cigarette box. The investigations of the Littering Control Council made it clearly evident that the issues are broad, complex and contentious, and so the Minister of the Environment decided in November 1972 to establish the Solid Waste Task Force. This group, once again, is composed almost entirely of concerned industrialists and merchants, along with consumer organizations and environmentally oriented groups. It is charged with examining tasks indicated by the Minister, along with other problems recognised by the Force. In view of the diverse issues, the Task Force operates by means of separate Working Groups formed to examine specific tasks. This mechanism permits the

Working Groups to comprise all interests vitally concerned with the task in hand. Each Working Group has the responsibility to investigate all aspects of the given problem and to prepare a report with recommendations. These reports will be reviewed by the main Task Force and forwarded to the Minister for his guidance.

Acting under instructions from the Minister, the Task Force has established two Working Groups. In chronological order the first is the Beverage Packaging Working Group, operating under the chairmanship of Mr. R.H. Woolvett. This Group is investigating beverage packaging. As a partial quotation from the Terms of Reference, it is to "investigate and measure the environmental, social and economic impacts resulting from the packaging of carbonated soft drinks, fermented beverages, distilled beverages, including their relationship to non-carbonated soft drinks or other beverages as may be desirable". As another partial quotation it "is to assess the social and economic impact in association with the prospective benefit to the environment and determine the various alternatives which may be used in connection with the packaging and marketing". This Group began work during the month of February and to the end of May has met nine times. The development of reliable data and projections has proved to be an onerous task. In spite of this, fired by a will to succeed, the task will be completed and a report written.

The Milk Packaging Working Group under the chairmanship of Mr. Roger Clarkson has also been at work since February. By the end of May five meetings have been held and the task is moving towards completion. Although difficult enough, this task has not proved to be as onerous or difficult as in the case of the beverages. The issues are not as complex, and there is a lesser prospect of causing disruption to established patterns.

During the early meetings of the main Task Force there was considerable debate over the directions along which the Force should move. There was a view that the most significant activity would be to examine the question of limiting the generation of waste at the source, and investigations dealing with the salvage and recycling of the various components of waste or, in other words, resource recovery. At the time the view prevailed that the first responsibility would be to examine specific problems as I have outlined earlier. Nevertheless, it was recognised that the broad issues of waste generation,

methods of handling and processing, and application of theories and practices of resource recovery should be carefully examined. In fact, it was recognised early in our work that these problems will be of lasting significance, which will require continuing investigation.

In progressing along these lines, the Secretariat submitted a proposal to the Minister outlining in some detail a proposed mechanism for establishing a new Working Group or function. This is to deal with the problems and opportunities posed by the salvage and effective use of many of the components of municipal, commercial, and industrial refuse. Interest in this relatively new dimension of waste management has been mounting for some time. The importance is clearly stated in the Terms of Reference for the Solid Waste Task Force. "The three paths along which effective progress in developing true solutions for the waste problems are :

1) adoption of significant policies providing for salvage of material and energy and large scale recycling of material.

2) return and re-use of articles and materials without entering into the disposal system.

3) reduction of the amount of waste which is generated."

It is proposed that a corporate structure be developed for the new activity, which provides for participation by the main streams of our social fabric. This includes the fields of Provincial Government, industry, Municipal Government and the academic community. Appropriate selection of members from these four groups will ensure that adequate knowledge, resources, and methods are brought to bear upon the very many facets of this complicated problem. It is high time that an authoritative body be established to examine the needs and undertake actual work as may be requisite to ensure that the maximum amount of useful and valuable material is salvaged and returned to the industrial stream for reprocessing into new material. In support of this view, I offer a quotation from a report of a speech delivered by Dr. Evans, President of the University of Toronto, to the Canadian Club, during the past February :

"Such problems might be solved by an organization that could draw upon the technical

and political resources of the entire community. We need a mechanism that would take each of these major public problems outside the university, outside government, and outside any particular industry".

Now to turn to the future. While it is hardly practicable, in the climate of today, to attempt any hard predictions, there is some prospect of outlining possibilities, particularly where these can result in some alleviation or improvement. On one point I think I am on firm ground. This is the question of design for disposal. It is difficult to accept that we can continue to ignore the very real needs of salvage, reclamation and disposal. If these become criteria for a designer, along with the commonly accepted factors of utility, appeal, and sometimes durability, the problems of waste management and resource recovery will be eased.

Can we contemplate Municipal collection and disposal on a basis of user charge? It seems to me that our present method of supplying unlimited service paid for from general revenue encourages the throw-away spirit. This conclusion is supported by the current runaway costs of medical care. There was a private contractor to the citizens of York County who made his charges through the sale of specially marked plastic bags. These were available to the public through various stores, and the contractor collected as many as were put out.

Is the alternative to see the eventual disappearance of individual collection? Many of the amenities and services which we have previously enjoyed have disappeard - grocery delivery; bread delivery; milk delivery, to suggest a few. Possibly we shall see area garbage depositories where we shall make our daily drop-offs. After all, we carry the stuff home in the first place.

These are a few random thoughts and I close with the plea that we strive to avoid neglecting positive action because we have not yet determined the perfect solution. We appear to investigate and debate endlessly, while by whittling away at the visible portions we can reduce the whole to a more readily digested mass.



T. B. Reynolds

ENVIRONMENTAL ASSESSMENTS - WHAT DO WE DO ABOUT THEM?

BY

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I was asked to speak to this conference on the role of the environmental impact statement. I have elected not to use the term "Environmental Impact" with its negative connotations and have adopted the Advisory Committee on Energy terminology "Environmental Assessment" which allows for beneficial as well as detrimental effects.

First of all let me disclaim any special expertise on this subject, although as a member of an industry which has been in the environmental limelight since the arousal of public concern in the early 1960's, I have had some exposure to it. I feel something like a virgin on her wedding night, looking forward with interest to what is going to happen, but still somewhat scared.

In Ontario, public concern over environmental deterioration of our quality of life is continuing to grow, and those of us who fail to recognize it are due for a sad surprise. As a society, however, Ontario has developed environmental regulations and controls which are a model for any jurisdiction.

My industry has been undergoing a comprehensive review for the last two years, and policies and problems related to future energy supplies are still undergoing serious study. Environmental effects of the industry have played a large part in the recommendations made as a result of these studies.

The Advisory Committee on Energy in its Volume 1 report, "Energy in Ontario The Outlook in Policy Implications" says "Environmental concerns must occupy an adequate place from the outset in all planning of programs and projects. Accordingly we recommend that the government of Ontario through its appropriate agencies implement a policy of requiring the preparation of environmental assessments of the environmental effects of all proposed programs and projects prior to their implementation relating to the production, conversion, transportation and use of energy by both public and private bodies." This was the first indication that some formal process might be required before Provincial Government approval to proceed with a major project is given. This recommendation is being translated into action through legislation to be introduced this year, as promised in the speech from the throne, to establish an Environmental Review Board. Those of you who have read the speech know that the proposal is to apply the requirement to both government and industry for projects with environmental implications.

We therefore have a pretty clear indication of intent that formal assessments will be required. The question now is, what do we do about them? It is important that we have an understanding of what we are talking about.

What is an Environmental Assessment?

I think it means, quite simply, a document prepared for the express purpose of predicting the environmental implications of proceeding with a particular project. This would include the effects on both the natural environment and the effects on the fabric of society, i.e. its socio-economic effects. Although the environmental movement started with concerns over the natural environment, the social aspects of major projects are becoming more and more important.

What should an Environmental Assessment contain?

I am continuously amazed at how little most people know of what is involved in one of our projects, whether it be a transmission line or a generating station, and I suspect the same is true of many of your projects.

Environmental Assessments must recognize this and should be used as a means of communication. They should include a thorough description of the proposed project, including all processes used, the environmental abatement procedures employed, a description of the existing social and physical environments, and an analysis of the environmental effects on both during construction and during operation; simplified site and plant layout drawings should be included.

It is desirable to tabulate those legal requirements which must be met and it is essential to describe the alternatives considered. These may include alternative sites for the project, alternative types of plants, or alternative processes within the plant, and might include the possibility of not proceeding with a particular project. The alternatives selected should be explained with reasons why they were selected.

What information will be used in the preparation of Environmental Assessments?

The biggest failure in the United States environmental impact statement procedure under the National Environmental Protection Act (NEPA), has been the lack of standard procedures for their preparation. Those responsible for drawing up the EA program must be prepared to issue some guidelines to be followed.

There is a tremendous amount of sociological and environmental data available in government offices and other locations which must be sought out, but as with any thorough investigation, on-site studies will almost certainly be required for any major project. In our case, we would not dream of building a generating station without a thorough on-site geological investigation, but in the past we have proceeded with such projects with little if any environmental investigation. This is not acceptable today.

What kinds of projects should require an Environmental Assessment?

The province has indicated that projects having significant environmental implications from both the public and private sector will require their preparation. This should avoid the ludicrous situation caused by the NEPA in the U.S., which required the preparation of an environmental impact statement for the remodelling of a small bank in New England because it was a Federal project, but exempted the construction of a project covering 26,000 acres of central Florida; that project

is called Disneyland. We have our own 20,000 acre project in Ontario which has come under attack because of the lack of environmental assessment. It is known as the Pickering Airport Project.

Most people in Ontario are now agreed that major high voltage transmission lines and the commitment of large thermal generating stations will require environmental assessments. In the same category, most probably, are new highways, pipelines, refineries, pulp and paper plants, sewage disposal plants and solid or liquid waste disposal sites and most certainly a proposal to establish a new airport.

What about the establishment of a large new park, dredging for a new harbour, development of a mineral resource, etc.? The list is endless and judgement will be required in determining what projects require the submission of an assessment.

Who should determine when an Environmental Assessment will be required, and who should be responsible for its preparation?

It is fairly obvious that the government must ultimately decide whether a statement will be required and legislation will be enacted to enforce them. Since this legislation has been promised this year, it behooves us from Industry to keep a needle eye out for it and examine it in detail when it is proposed. Some form of guidelines for the preparation of environmental assessment will be necessary and in the same spirit, these must be examined carefully. Any proposal which requires the approval of a government ministry or is a candidate for public funds in the form of loans or grants and has the required environmental implications, is likely to be a potential subject. I suspect that those of us who have previously made application to a government ministry as required under various Acts as a matter of course will be surprised to learn that such approval may not be given in the future without the presentation of an Environmental Assessment.

It is likely that Industry will be made responsible for the preparation of assessments, to guidelines proposed by whatever government agency is ultimately made responsible for their evaluation. This in my opinion, is the logical course of events, with Industry responsible for preparing the assessments, and government responsible for evaluating and approving them.

When should the Assessment be prepared?

Under the NEPA in the U.S. a draft statement is required to be circulated at least 90 days in advance of a proposed action. This timing would appear to be desirable but if a public hearing process is used, it must be considered as an absolute minimum.

What happens to the Environmental Assessment after it is prepared?

At the present time this is an area of pure speculation. To serve a useful purpose the Assessments must receive appropriate distribution to the government ministries or agencies responsible for the necessary approvals for their comments, but to serve the full purpose of the intent, they must be made available to the interested members of the public.

There are several potential administrative procedures for Environmental Assessments, most of which would require them to be referred to the proposed Environmental Protection Agency, which will be responsible for evaluating the environmental impact and ruling whether a project is environmentally acceptable. As part of this process it will be required to make a decision on the necessity or appropriateness of a public hearing. I expect that in most cases where an environmental assessment is called for, the public hearing will be mandatory. It is important that this process not be used by politicians as merely a delaying mechanism in the approval procedure, but that it form a real part of public participation.

Speaking from some limited experience in this area, there is no process likely to build a consciousness of environmental matters more quickly than a full disclosure and public hearing process.

Public hearings by their nature tend to polarize the participants into confrontation. At Ontario Hydro we believe this to be undesirable and therefore we are attempting to determine the public concerns well in advance of completing our proposals and incorporating their ideas where possible in our plans, in the expectation that such confrontation will be considerably minimized.

It must be recognized under the public hearing process that a decision on the environmental acceptability of a proposal will be squarely laid to those responsible for ruling on the assessment. Public input, therefore, is important.

Public Participation

Public participation, open planning, citizen involvement or whatever else it is called is becoming a way of life in Ontario in the 1970's. The winds of change are blowing and politicians, civil servants, industry and individuals are quickly becoming exposed to it. The evidence of gross changes in public value judgments with respect to government and industry decisions is everywhere. The Spadina Expressway, the Pickering Airport, the Minto and Port Hope garbage disposal projects, the Algonquin, Quetico and Waterfront Park proposals, Ontario Hydro's Beverly Street Transformer Station and our 500KV Nanticoke to Pickering transmission line are all recent examples of decisions and proposals by executives, or by elected officials, which have been drastically affected by input, both invited and uninvited, from the general public. The public no longer acquiesces gracefully to decisions made on their behalf which they believe intimately affect their lives. The pulse of this trend is quickening, in university students' unrest, women's liberation, Regional development plans rejected, shareholder revolts at annual meetings, and revisions to government budgets, all examples of public participation. It would not surprise me in the future if government budgets are issued in draft form for public consumption and discussion before they are implemented. The budget prepared in secret and imposed in mandarin fashion has its problems.

What are the implications of this trend?

There are serious dangers in the process of direct public participation, but there are also significant opportunities. The most serious danger is that public participation in planning bypasses the historic democratic process. In other words, it can represent an end run around government. It can also be considered the ultimate in the democratic process, provided the participation is representative of the majority of the people. Unfortunately this is seldom so, although it may represent the majority of the people directly affected. The danger is that the proper decision in the interests of the general public can be bastardized by the interests of the participating public. The opinions of the silent majority must also be brought out somehow.

The process of public participation in planning also provides for significant opportunities. At an environmental workshop for Canadian Electrical Utilities I attended in May, there was unanimous agreement that public participation in the planning of utility projects

was desirable, and could result in better decisions, faster approvals, less regulatory confrontation, and more publicly acceptable projects.

Many of those in our industry who have become involved in the public participation process believe that something fruitful will result from this belly-to-belly experience with our harshest critics, although I have also heard the process described as similar to micturition. For those of you who do not have their dictionaries handy, that means - a voluntary pants-wetting.

In Ontario Hydro we are working very hard to develop procedures for involving the public in our planning. This has been strongly recommended to us by Task Force Hydro, by the Advisory Committee on Energy, by the Solandt Commission, by the general public, and our own Commission has endorsed it as future policy. There are many for whom this seems a heretic step, although I believe in the long run there is little downside risk, and opportunity for significant gain. These are the trends I look for in the stock market those few times I have spare resources to invest.

Our company has been noted over the years as one which provides reliable service. Recently we have found that it is essential to listen with a new ear in order to maintain this same order of service. In my opinion this experience is providing new vitality within the company, particularly among the younger members.

Public participation in our planning will result in an informed, educated public, some of whom are likely to end up with a better overall knowledge of our corporate operation than many senior people in the company. In the process some of them become our strongest advocates.

Well, Environmental Assessments, what do we do about them? I recommend that we get staff trained and prepared to meet this new challenge. We must re-examine objectives and plans in the light of what the public expects of us, and watch for new trends in our society. They are there to be seen. Society is developing totally new expectations from government and industry and we must live up to them.

In this twentieth year of operation, the Conference Committee considered it fitting and timely that it include a scheduled "Conference Wrap-up" at which a well-known delegate to these conferences would give his views regarding the content and presentation of these papers.

Mr. Hugo Holland, who made the wrap-up remarks for this conference, has been an active supporter of these Industrial Waste Conferences for many years. This, with his background in pollution control with Imperial Oil, provided him with an insight into the types of material delegates to this conference wish to hear while the papers are being presented.

His remarks are provided in the following pages.

WRAP-UP - A REVIEW OF THE 20TH ONTARIO INDUSTRIAL WASTE CONFERENCE

BY



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INTRODUCTION

My first Ontario Industrial Waste Conference was the 13th, held at Bigwin Inn in 1964. Since then I have had the good fortune to attend most of these annual gatherings. This has been an entertaining and generally instructive series of experiences leaving me with many pleasant memories. In any case it gave me courage to accept Fred Voege's invitation to present what he then termed "an overview of the 20th Conference" against the background of those which had preceded it in the hope of suggesting some guideposts for those which are to follow:

THE SESSIONS

For the first time, at this Conference, there has been a deliberate attempt to establish sessions on a broad theme and concentrate the papers on these topics within them.

For a program committee which only knows the nature of the presentations when the papers arrive at the last moment, this is an exercise in clairvoyance. For a reviewer in my position there is a necessity to regroup the papers on content rather than title.

Accordingly, my first classification is Government-Industry Relationship and under it I shall consider four papers rather than the two listed in the program.

The papers by Professor Judy and Professor Knelman continue the trend to examining the broader economic and philosophic aspects of protecting the environment which we tend to neglect in our preoccupations with the day-to-day problems of pollution control. This was started in 1969 by Professor J.H. Dale (An Economist's Approach to the Problems of Water Pollution), continued in 1971 by A.V. Kneese (Incentives and Environmental Management) and Professor D.A. Chant (The Role of Public Pressure Groups in Environmental Control), and in 1972 by K.C. Lucas (Federal Government Activities in Industrial Pollution Control).

Having had an opportunity to read Professor Judy's paper, I can appreciate that it is a useful continuation of the tradition established by these gentlemen. Unfortunately, it proved to be one that did not lend itself to impromptu condensation so I suggest that you read it for yourselves.

As usual, Professor Knelman's presentation was most stimulating. However, as a profession we are accepting and applying accommodation to the resolution of "great problems" and I am not responsive to appeals to a crusade against the "apostles of growth".

On this basis, I rate Mr. Heaman's description of the success of the working groups of the Solid Waste Task Force as the outstanding contribution to the philosophy of environmental protection from this conference. Here is accommodation at work in the real world, producing viable solutions to specific problems.

The final paper in this group is Mr. Belling's on the provincial contingency plan for spills. I was encouraged by his examples of field successes but can only hope that it will not be tested on a massive scale.

TECHNICAL SESSIONS

A review of the technical papers presented over the years to the Ontario Industrial Waste Conferences is an index of the topical interests of the profession and the control agency. Some abatement processes appear first as research reports, then progress through the new application stage to fully proven treatment applied to a widening variety of industries. Others, like deep well disposal, enjoy brief periods of respectability before being outlawed. But, through it all, biological treatment rolls majestically along as the mainstay of our endeavours. It is appropriate that there should be a full session on biological treatment and five papers concerned with varying aspects of its application. However, I prefer to review on a different basis.

I feel that the success of the technical aspects of these conferences is founded on a long series of sound, no-nonsense accounts of field experiences with waste treatment processes - some successful, some not, but with no attempt to hide the warts and blemishes. In this conference we have four contributions of this type:

J.D. Norman & B. Sayer
"Development and Implementation of a Two-Stage Biological Process for Treating a Strong Organic Waste"

K.C. Bradley & F.M. Hager
"Water Pollution Control at a Multi-Product Organic Chemical Plant - A Case History"

J.B. Greenshields, N.J. Czornyj & T.A. Constantine
"Development of a Refinery Waste Water Treating System"

J.B. Knapp
"Water Reclamation and Re-Use at Brenda Mines Ltd."

These were good solid examples of the genera. Like the female Hippopotamus, they may appeal only to a male of the same species, but there is a wealth of solid meat in them.

The next most numerous category is the research/ new applications group where we find:

M.R. Cameron & A.D. Fitzgerald
"Cold Weather Operation of Mechanically Aerated Lagoons"

D.C. Climenhage & A. Stelzig
"Biological Process for Nitrogen - BOD Removal at Maitland Works, DuPont of Canada Limited"

D.C. Cook & J.H. Linton
"Pollution Abatement Through By-Product Development".

Finally, over the years we have had a number of good papers in the analytical field and this year is no exception:

T.B. Reynolds
"Environmental Assessments - What Do We Do About Them?"
and

D. Wells
"Biomonitoring of Petrochemical Waste Waters".

These may seem a far cry from the 4 amino anti-pyrene method but they're very much the shape of things to come - ask anyone wrestling with Environment Canada's concerns over toxicity to fish and Environment Ontario's hopes to protect fish flesh flavour.

However, as objectives become standards, we will be back to more classical analysis since the attainment and maintenance of analytical accuracy will be at a premium.

At this point I must say with regret that what enlightenment I've got at this conference has come largely from reading the papers, not from hearing or seeing them. Despite Fred Voege's pleas over the years - too many authors read their papers and too many of the graphs and tables were invisible. I would recommend to the Committee that in future they demand that the papers be completed at least a month ahead of the conference to ensure that the illustrations be comprehensible.

So much for what we heard, now let us consider what we did not: while the continued growth of these conferences

must be gratifying to the organizers, it has not been without a price. As the meetings have grown larger, they have become much more formal and less intimate and relaxed. There is much less opportunity for the free exchange of news and views between friends with different affiliations. One of the things that shocked me most at the first large environmental meeting that I attended in the U.S.A. was the attitude of "Cabot speaks only to Abbott and Abbott speaks only to God"; that separated Federal, State, University and Industry.

I think future committees must recognize this and arrange to provide the answers either formally or informally to such important but non-technical questions as:

In the struggle for political control of pollution, does the province intend to protect industry from excessive duplication of permits, licenses, reports, samples and analyses?

Is the program for removing phosphate from domestic sewage a success? Economically justified?

In the long-range land use planning that is going on, is adequate consideration being given to pollution control? To protective zoning for industry?

Is the U.S.A. really preparing to fight pollution in the Great Lakes?

Finally, while it may be a mark of maturity, it was with regret that I found that this was the first conference without an author working in the U.S.A. We have a unique opportunity to draw on American experience and counsel which has been offered freely in the past. We should not abandon it.

In summary, this has been a good conference and I hope and trust that number 21 will be at least as successful.

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